THE ANATOMICAL STUDY OF THE GROWTH ACTIVITIES OF GUAVA

THESIS SUBMITTED FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

BOTANY

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ALIGARH MUSLIM UNIVERSITY
ALIGARH

1977

SUMMARY

The anatomical study on the growth activities of guava (*Psidium guajava*) has been carried out for three consecutive years starting from 1974. The results are summarised below:

The extension growth normally starts from late February or early March and continues upto the end of October. Its rate slows down considerably during May and June giving rise to an apparent break in growth.

The new leaves appear throughout the period of extension growth. With the production of new leaves, new axi-llary buds arise. These buds develop into short branches and produce floral buds and dry up with the ripening of the fruits.

The flowering occurs in two flushes, the first from the middle of March to May and the second from July to September.

The extension growth in seedlings starts from February and continues upto October without any apparent break.

The shoot apex possesses a distinct tunica layer and a mass of corpus cells constituting the distal, the proximal and the peripheral zones. During the differentiation of primary vascular elements, phloem formation precedes xylem in

the shoot axis as well as in the leaf axis.

Transections of young shoots are quadrangular in outline. The cortex bears a number of secretory ducts of various dimensions. Next to cortex, a continuous cylinder of thick walled parenchyma represents the pericycle which encloses a vascular cylinder, with a centrally placed parenchymatous pith. On the periphery of the pericycle, develops a discontinuous fibre ring. In nodal regions brachysclereids develop in the cortex and pith.

Roots are tetrarch.

The first phellogen initiates in the pericycle both in root and shoot. Subsequent periderms replace the older ones in older shoot axes.

The petiole and midrib have a crescent shaped vascular strand with incurved ends. The secretory ducts develop below the epidermis. The mesophyll of blade differentiates into palisade and spongy parenchyma. A distinct multilayered hypodermis develops below the adaxial surface.

A foliar cambium, with distinct ray and fusiform initials, develops in the main vascular strands of leaves and petiole, and produce some secondary elements.

The vascular cambium is non-stratified and is made up of fusiform and ray initials. The fusiform initials vary in

length from 308-423/u. The nuclear number in fusiform cells varies from 1-5 per initial. The number, size, shape and the chromaticity of the nucleus as well as the thickness of radial walls of fusiform initials appear to undergo considerable seasonal variations.

The number of cambial layers goes high in the month of April and August. The fusiform initials attain maximal size (397/u) in July. The frequency of the uni-seriate ray initial units appear more in August and September.

Changes in the cambial make up also occur with the growing age of the axis. The fusiform initials undergo gradual elongation with the growing age of the axis. The ray initials mainly multiply to become more in number. The ray initial units become broad and occupy greater area in the older axes than the younger ones.

The wood of guava is diffuse porous. The axial parenchyma is apotracheal and diffuse. The wood rays are heterogenous and vary in height ffom 1-40 cells and in width from 1-5 cells.

The vessel size varies with the season and age of the plant. The short vessels are more frequent in the younger ones than in the older trunks.

The bark of adult trees is non-fibrous and is made up of conducting and non-conducting zone. The extent of cross-sectional area of sieve-tube elements varies from 33-43% in a calendar year.

The vascular cambium undergoes activation twice in a year, after undergoing definite periods of rest. The first sign of activity occurs in March, with the swelling phenomenon taking place in the last week of March. The actual cell division occurs in early April. In May the activity stops and the cambium becomes dormant again. In mid-July the cambial zone again undergoes swelling phenomenon. The actual cell divisions start in late-July or in early-August, and the new cells continue to form upto October. Thus, the second phase of cambial activity extends for about 3 months. The total period of cambial activity, including the temporary phase of dormancy is about 8 months in this plant.

During both the phases of activity the xylem formation precedes phloem. The amount of phloem produced in a calendar year measures about 400/u in depth. The annual increment of xylem, on the other hand, amounts only to 150-200/u.

The phloem produced out of the first flush of cambial activity functions for about 5 months. The major part of the phloem of second flush (in September-October) becomes inactive in November and December of the same year. A narrow strip, amounting upto 30/u in depth, of the second flush, remains active till April next. Thus the longevity of phloem of second flush extends for about 7 months.

Extension and radial growth in Psidium occur in two apparent flushes. The extension growth always precedes the radial growth by 3-4 weeks. The cessation of cambial activity in trunks and the end of extension growth in twigs occur more or less at the same time.

In the name of Allah, the Beneficient, the merciful.

My Lord! Relieve my mind
And ease my task for me;
And loose a knot from my tongue,
That they may understand my saying.

Al Koran.

CERTIFICATE

This is to certify that the thesis entitled " THE ANATOMICAL STUDY OF THE GROWTH ACTIVITIES OF GUAVA ", being submitted to the Aligarh Muslim University, Aligarh, for the award of the degree of Doctor of Philosophy, is a faithful record of the bonafide research work carried out by Mr. Mohd. Ishrat Husain Khan. No part of the thesis has been submitted for any other degree or diploma.

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ACKNOWLEDGMENT

I am thankful to none but the One who inspired and guided me in this endeavour.

I put on record my high regards to my reverend teacher Prof. K.A. Chowdhury for suggesting the problem and initiating the work.

I appreciate sincerely the spirit with which Dr. A.K.M. Ghouse has worked with me throughout the period of this work. I am grateful to him for all that he has done personally by himself and also getting me others assistance. Without his incessant encouragement, incredit-able guidance, constructive criticism and consistent care this work would not have come to completion today. I earnestly pray to Almight to provide him with enough faith and courage in his mission of life Amin.

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CONTENTS

INTRODUCTION

The guava (Amrood), one of the most common fruits of the country, is of great economic importance, as large productions of this fruit are sold at moderate prices all over the country. The tree is very hardy, growing with little attention, or is even wild. The common guava (Psidium guajava L.) is a native of tropical America. It originated along with a number of other important fruits, in tropical America, and found to have been growing from Mexico to Peru by various European explorers. It has now spread throughout the tropics and subtropics.

It is not known how and when the guava reached India. It is believed that it might have been introduced in this country at a very early date before the 17th century (Hayes, 1957).

The guava (Psidium guajava L.) is a medium sized tree, about 30 feet in height and shows extensive false dichotomous branching (Plate I). The main trunk as well as the lateral branches show pale-brown bark, peeling off in thin flakes. Young and green twigs are quadrangular, slightly winged, leaves elleptic-oblong, 4-10 x 3-4.5 cm, obtuse apex, sub-coriaceous petiole, 3-4 mm long. Flowers on 1-3 flowered axillary peduncles, sometimes 5-7 flowered; flowers actino-morphic, 4-5 merous, white. Sepals 4-5, connate in the bud

stage, splitting into 4-5 fid unequal lobes at anthesis. Petals 5, free. 1.5-2.0 cm long, caducuous, imbricate, stamen numerous, free; filaments filiform, incurved in bud; anthers linear-oblong, dorsifixed, splitting longitudinally. Carpels 4-5, syncarpous; ovary inferior, 4-5 celled, numerous ovules on 2-lamellate placenta; style 1, simple, slightly hairy; stigma simple. Fruit globose, pyriform berry with persistent calyx-lobes, vary in size, usually 3.5-7.5 cm across, many seeded. Seeds numerous, hard, sub-remiform, 1.5-2.0 mm across (Husain 1970).

Distribution: The guava is now found throughout India and more than half of the entire acreage grow in Uttar Pradesh (Table-1). However, a recent publication of I.C.A.R. (Nath 1963) shows only 23,986 acres to be under guava cultivation in U.P. and a total of 68,547 acres in the whole of the country. However, in both the counts the Uttar Pradesh leads in guava orchards.

Uttar Pradesh is by far the most important guava producing State of India and Allahabad has the reputation of growing the best guava in the country. Guava is found to grow very satisfactorily in all parts of Uttar Pradesh below 3,000 feet altitude. According to Seth et al. (1971) Allahabad produces the most delicious and famous 'Safeda' variety of guava and this district alone accounts for more than 18 per cent of the total area (2262 hectares) under guava in the State.

TABLE 1.

Estimated area under Guavas in some parts of India adopted from Hayes (1957).

State	Area in acres
Andhra and Madras	2,550
Assam	1,200
Baroda	915
Bhopal	206
Bihar	19,932
Bombay	8,100
Coorg	50
Hyderabad	4,800
Madhya Bharat	2,700
Madhya Pradesh	11,209
Mysore	1,000
Orissa	600
Saurashtra	15
Uttar Pradesh	70,000
West Bengal	2,000
Total	1,25,327

Apart from Allahabad, other districts of the State both in Eastern as well as in Western U.P. including Aligarh are fairly known for guava cultivation. Sasni, a town area in Hathras Tehsil of Aligarh district is equally famous for 'Safeda' variety in the Western districts of Uttar Pradesh.

Flowering: In Uttar Pradesh and other parts of Northern India, guava flowers twice a year, once in February and subsequently in June. The February or spring flowering is called Ambe-bahar and the June or monsoon flowering is called Mrig-bahar. The first crop of fruit from the February flowering ripens from July to September during the rainy season and the second crop from June flowering ripens from November to January in the winter. However, Husain (1970) has reported flowering period Ambe-bahar from May-June and Mrig-bahar from September-October and ripening of the fruits from August-September and December-January respectively in Aligarh. The guava fruit takes about 5 months time from the flowering to the ripening stage. The growth period of the fruit in South Africa varies from 115 to 280 days, according to Le Riche (1946).

In Western and Southern India, the guava tree flowers thrice in a year in February, June and October and this third floral flush is called Hasth-bahar. Due to the successive three floral crops, the guava in these parts of the country

appears to bear fruit almost throughout the year.

Control of crops: The Ambe-bahar fruits ripening in the rains from June-August are insipid and watery, and susceptible to various pests; but the Mrig-bahar fruits ripening from November-January are excellent in quality. In most parts of India, therefore, the guava trees are made to produce the Mrig-bahar flowering only which is directly controlled by stopping the irrigation of the trees from February till the middle of May. In that case, any young fruit which sets in the spring (February) will fall off. The unirrigated trees will drop most of their leaves during the hot weather (April and May) and will take rest. At the end of May or early June, the soil of the orchard is ploughed, harrowed or hand dug and each tree is individually manured and soon they are irrigated. The first two waterings are given at an interval of three days and subsequent at interval of 10-15 days till the monsoon sets in. Within 20 days of first watering, the trees produce heavy flush of flowers by the end of June and continue to do so during July.

The Hasth-bahar flowering, as it depends upon the vagaries of the monsoon, it is not possible to control the flowering of this crop by giving special cultural treatment as in the case of Ambe-bahar and Mrig-bahar. The Hasth-bahar is, therefore, at the most a chance crop.

Root exposure practice for regulating the floral production is also very common in the different regions of the country having highly retentive clay soils. The upper three inches soil layer is removed and the roots are exposed; as a result water supply from the soil to the top is reduced to the minimum and, therefore, the leaves begin to drop and the trees go to rest. The roots are again covered with the original soil and after giving sufficient manure, the orchards are immediately watered. As a result the trees blossom heavily within 1-2 weeks time.

Pruning: Oppenheimer (1947) recommended pruning which will keep the tree low enough so that the fruit may be harvested by hand from the ground. Dasarathy (1951) noted that in Madras most of the fruit bearing branches die after the fruit matures and recommended the pruning of such portions from time to time. The bending of the branches is also recommended by Cheema & Deshmukh (1927) who found suitable results in Ganeshkind Gardens. Gadgil & Gadgil (1933) noted the effects of bending in the alternate years and the trees were found bearing upto 300 fruits per tree. However, some growers do pruning of the trees to give them beautiful and ornamental look in the gardens and are not much curious about the yield.

Production: The bearing life of the trees depends on the treatment they receive but generally they behave normally and

give good yield upto 30-40 years of age, provided they are not seriously affected by disease. Kulkarni (1911) reported that plantations generally last about 40 years, but they deteriorate after 15 years.

Accurate production figures are not available. However, some approximate figures have been worked out by various workers. Oppenheimer (1947) reported an average 110 lb. per tree. Ibrahim (1943) reported average number of fruits from 100-300 in the rainy season and 300-500 fruits in the winter. Naik (1949) reported that at Kodur a red-fleshed variety yields more than 700 fruits a year, Allahabad varieties about 500, and a seedless variety about 125 only. Prasad (1936) reported 450 fruits per tree in Allahabad district. Barakzai (1920) estimated average yield at only 30 or 40 lb. per tree. Rao (1946), Chattopadhyay & Sen Gupta (1955) have reported 2.2 to 4.5 tonnes yield per acre in different regions of India.

According to a recent survey by Seth et al. (1971) the average yield of guava per bearing tree varied considerably from year to year and region to region and it was generally higher in Doab region as compared to that of other places. The average yield per bearing tree was estimated to be 17.6 kg with a standard error of 5.3 per cent. In terms of number of fruits, the average yield per tree was estimated to be 150 fruits with a standard error of 4.3 per cent. On the basis of the number of trees per hectare, the average yield per hectare was estimated to be 65 quintals.

Propagation: The guava is usually propagated from seeds in all parts of India and many other countries. Seeds ordinarily germinate readily in two or three weeks and may take a longer time under unfavourable conditions. Guava seeds retain their vitality for about a year after they are extracted from the fruit.

Seedling from a specially selected, uniform lot of fruits showed great variations in size, shape, quality and season of ripening, in an experiment at the Agriculture Institute, Allahabad. Du Preez (1943) noted that seedlings raised from a single fruit may bear fruit varying in colour from white to pink and considerable variation in the yield of seedlings. To avoid these variations in the quality of the fruits and yield, the vegetative method such as 'inarching' or 'layering' is done to raise the grafts. Inarching of guava is done in the same way as of mango. But with grafted trees intensive care is needed to prune out the buds and branches produced by the stock plant.

The best time for planting guava in most part of the Northern and Western India is the South-West monsoon i.e., from June to August. In parts of Southern India, which get the South-west as well as the North-East monsoon it may be planted in any of the two rainy seasons depending on the amount of the rainfall.

The trees are generally planted 15-20 feet apart in the Southern regions and 20-25 feet apart in the Doab region and near the bank of rivers as they grow comparatively larger

in size than the Southern regions. In Uttar Pradesh 20-25 feet distance is recommended by the horticulturists.

Varieties: In Uttar Pradesh, there are three well known varieties, they are Safeda, Chittidar and Karela. The most popular among them is 'Safeda' which is a round, smooth skinned, white fleshed, sweet guava and it is also introduced in many other parts of India. The Chittidar is almost similar to 'Safeda' but with red spots on the skin and white pulp. The Karela is pear shaped, has a rough skin and white sweet pulp.

Seedless varieties are very common in several parts of the country and one of this was found to be triploid with 33 chromosomes instead of the normal 22 (Kumar & Ranade 1952).

Lucknow 49, which is recommended by the Bombay Department of Agriculture for growing in Bombay-Deccan competes in various aspects with 'Safeda' variety. It has a 3/4 inch thick, seedless shell and fewer seeds embedded in the central pulp. Ramasomayazulu (1953) noted better crops of Lucknow 49 in the Araku valley, at about 3,000 ft. elevation in Andhra. This variety is also among the promising ones tested at Kodur, according to Rangacharlu (1954).

Roy & Ahmed (1951) have described the varieties Harijha, Safeda, Habshi and seedless as grown in Bihar.

In Bombay-Deccan, two varieties are chiefly cultivated viz., Nasik and Dharwar. The Nasik is pear-shaped fruit with a long, high neck and the Dharwar is elleptical in shape.

These varieties are suitable for long distance transportation due to their hard flush. Dholka variety is also very common in Lucknow orchards.

Climate and soil: The crops of better quality are generally obtained in the well irrigated regions of the country having dry moderate winter and summer with annual rainfall of about 40 inches. The guava is more resistant to drought and fruits can stand well upto 115°F. But it is highly susceptible to frost. It succeeds in nearly every type of soil. Ruehele(1948) states that in Florida the guava thrives well on light soils with pH value as low as 4.6, and on limestone and marl soils with a value upto 8.2.

Guava responds most generously to cultivation, manuring and irrigation than other fruiting trees and sometimes it grows and produces fruits on soil too poor for most of the fruits.

Economic importance: The guava is a fruit of moderate quality and it is very popular as a fresh fruit, as well as for the manufacture of jelly and other products. It is a valuable food, but the actual composition varies greatly. The composition of different components has been worked out by a number of workers (Thompson 1914, Popenoe 1920, Oppenheimer 1947, Riaz-ur-Rahman et al. 1954, Singh & Mathur 1954).

The outstanding value of the guava as a source of vitamin C (and its ascorbic acid content) has been recognized by various workers in India and other countries (Golberg & Levy 1941, Hyward 1942, Boyes & De Villiers 1942, Isac 1942, Webber 1942, 1944, Van der Merwe 1944, Godston & Chamin 1945, 1946, Miller & Basore 1945, Aykroyd 1951, Rias-ur-Rahman et al. 1954.

The content of other vitamins is much less in guava. Miller & Basore (1945) reported guava as a fair source of vitamin A in Hawaii but poor source of thiamine. Campos (1943), however, claimed that in Brazil it is a good source of both thiamine and riboflavin.

Guava jelly and cheese is an important product in India, and in some other countries in the form in which the fruit is commonly used. Some information regarding this aspect is furnished in the literature by Abbot (1931), Coit (1946) and Ruehle (1948). Canning of fully ripened guavas is also very common in India.

Guava nectar and paste is also prepared by various methods and is very common in the market.

The leaves of guava as rich source of tannins (8-15%), are used for tanning in sole and heavy leather tannage. The leaves contain a yellowish green or yellowish red essential oil having pleasant agreeable odour. Oil of the guava leaves is aromatic and is useful as flavouring agent. It inhibits the

growth of Escherichia coli, Bacillus subtilis and Micrococcus pyogenes var. aureus. Leaves also contain wax, resins, sugars, carotene, vitamins B1, B2, B6, niacin and vitamin C.

The bark of the guava tree contains considerable amount of tannins (11-27%), and is used for tanning and dyeing purposes. Leucocyanidin, Luteic acid, ellagic acid and amritoside have been isolated from the stem bark. It is valued for its astringent properties and has been employed in diarrhoea in children.

The wood is smooth and works well. It is used for wood-engraving and for spear-handles, instruments and for lac-turnery.

The flowers are said to cool the body and are used in bronchitis. They are also applied to eye sores. The fruit is tonic, cooling and laxative. It is good in colic and for bleeding gums. The fruit and its conserves are astringent and used in diarrhoea and dysentery.

A perusal of literature on guava (Psidium guajava L.) has revealed that no serious work on the growth as well as the anatomical aspects has so far been done. All that appeared in the literature about the anatomy of this plant is the general description of Metcalf & Chalk (1950).

Keeping in view the above, the present work on guava was undertaken with an aim to provide all available information regarding the growth activities of this species under local climatic conditions. Under this project, radial growth

was included in order to find out the behaviour of vascular cambium and its derivatives in a tropical fruit tree under sub-tropical climate, influenced by regular monsoon rains.

The present work includes the following aspects of study:

1. Phenology.
2. Extension growth of seedlings and twigs of adult trees.
3. Anatomy of the shoot apex and the development of primary vascular elements.
4. Development and differentiation of leaves.
5. Structure of leaf and the mechanism of leaf fall.
6. Formation of axillary buds.
7. Formation of floral buds.
8. Studies on primary structure of shoot and root.
9. Formation of vascular cambium and its derivatives.
10. Formation of periderm and lenticels.
11. Ageing effect on the structure of cambium, wood and bark.
12. Seasonal effect on the structure of cambium, wood and bark.
13. Periodicity of cambium, phloem and xylem production.
14. Longevity of phloem and
15. Relation between extension and radial growth.

GEOGRAPHY

The district of Aligarh is situated in the North of Uttar Pradesh. It is bounded by the river Ganges and Jamuna for short distances. The extreme parallels of latitude are 27° 29' and 28° 11' N and 77° 29' and 78° 38' E longitude, with an area of 5069.66 sq. km. The length from North to South is 72 km; the breadth from East to West is about 112 km.

The following localities are important from vegetation point of view of Guava orchards in Aligarh District:

Government Agriculture Farm, Kuarsi: The Government Agriculture Farm is situated at 27° 56' N latitude and 78° 9' E longitude. It is at a distance of about 4 km. Northeast from University Mosque. The site is near the rajbaha (distributory) of the Ganges canal. The guava orchards are on the Southern side of the rajbaha.

Jalali: The town is situated in 27° 62' N latitude and 78° 15' E longitude at a distance of 20 km. East of Aligarh. On either side of the town flows a large distributory of the Ganges canal.

Jawahar Park: The Jawahar Park also known as Naqvi Park is situated near the University Mosque at a distance of about

1/2 km. The Jawahar Park is well known in the district for its delicious varieties of guava.

Sasni: On the Aligarh Agra Road in the tehsil of Hathras at a distance of about 15 km. from Aligarh, Sasni is situated at 27° 34' N latitude and 78° 5' E longitude. It is well known for its superior Psidium varieties and is called a place of guavas in the Agra and Aligarh districts.

Civil Lines: Dodhpur is a residential locality situated about 2 km. from the University Mosque. In this locality almost all the bungalows bear a mini orchard of guava.

The Psidium being a medium sized and high fruit yielding tree is grown in most of the kitchen gardens and courtyards of almost all big houses and bungalows.

WEATHER CONDITIONS

Aligarh experiences the tropical monsoon type of climate with its characteristic seasonal rhythm, marked by the North-East and North-West monsoons. The North-East monsoon season, from December to mid June, is characterised by dry winds of continental origin and is marked by extremes of temperature, clear skies, occasionally dusty, and low relative humidity. The remaining period of the year, that is from mid June to October, is influenced by humid winds of oceanic origin, and its main characteristics are cloudy weather, occasionally heavy rainfall and high relative humidity. Depending on the weather conditions, the year can be divided climatically into three main seasons:

1. The winter (mid October-March)
2. The summer (April-June)
3. The rainy season (mid June- mid October).

It is an established fact that the various growth activities of the plants growing at a particular place or locality are affected in various ways by the climate of the locality. Thus, the detailed study of the various climatic variations and factors is essential for the clear understanding of the impact of these factors on the behaviour of the tree.

The climatic factors that play the major role in determining the growth activities, leaf fall and fruit production, etc. are:

i) Temperature
ii) Rainfall
iii) Relative humidity
iv) Wind velocity, dust storms, etc.

Analysis of the data obtained from the meteorological Section of the Physics Department, Aligarh Muslim University, Aligarh, during 1974, 1975 and 1976 revealed that the climatic conditions of Aligarh are at their extremes.

i) Temperature: Aligarh experiences great extremes of temperature. The beginning of winter season is marked by a considerable fall in the temperature. The mean monthly temperature falls from 19.9°C in November to 15°C in December and a further fall in January when the mercury sometimes touches 13.4°C. December and January are the coldest months of the year during which the average temperature ranges between 13.4°C and 15°C, while May and June are the hotest ones when the average temperature goes upto 33.20°C (Table 2). The average monthly temperature in °C (maximum and minimum) are given in Fig. 1.

ii) Rainfall: On account of the excessive heat of summer months low pressure is developed in North-West India and by the middle or end of June it brings a complete reversal in the

TABLE 2.

Mean monthly temperature in degree centigrade during 1974, 1975 and 1976.

Month	1974	1975	1976
January	13.7	13.4	14.8
February	14.5	15.4	16.7
March	23.1	21.1	21.2
April	29.5	28.2	27.4
May	32.5	32.3	31.1
June	33.2	30.5	30.8
July	31.5	29.2	30.1
August	29.1	28.5	27.8
September	29.4	28.4	28.9
October	25.6	26.8	28.1
November	19.5	17.9	22.3
December	14.2	14.8	16.0

movement of the air current. With the arrival of the humid oceanic currents, temperature fall , accompanied by high relative humidity.

The time of the onset and retreat of the monsoon varies considerably from year to year. The rains generally set in by the middle of June and continue till the end of September or early October. It is in this period of the year that Aligarh receives about 90% of the total annual precipitation. Figure 2 shows that the monthly distribution of the rainfall throughout the year is not uniform. Usually the rains start by the middle of June, remain steady in July and August and then decline in September. The month of June receives an average of 46 mm whereas the average for July, August and September is 277.6mm; 252.3 mm and 125.9 mm respectively. There is a marked decrease in rainfall by the end of September and October. It is evident that July and August account for about 60% of the annual rainfall. The withdrawal of the South-West monsoon takes place usually by the third week of September or early October, is marked by the rainless intervals, and retreat of monsoon takes place by a series of intermittent rain and dry weather. The precipitation in October sometimes falls upto 0 mm. The amount of annual rainfall ranges from 650 to 937 mm. The amount of rainfall during the winter season is small, irregular and sporadic. It may be pointed out here that the winter rainfall, though small, in magnitude is highly beneficial to the rabi crop.

iii) Relative Humidity: The monthly average of relative humidity ranges from 29.3-80.6% during the year. The month of April is the driest (RH 29.3%), but soon after the monsoon, humidity goes up and remains so during July, August and September (Table 3). The average relative humidity in percentage at 8.30 and 17.30 hours is given in Fig. 3.

iv) Wind and Dust Storms etc.: The prevailing direction of wind during the winter season is from West and North-West to South and South-East. The winds during this season are very high and generally blow at an average speed of about 3.5 km/hr. These winds are of continental origin and are, therefore, mostly dry. During the summer season hot and dry westerly winds of considerable velocity, blow from 10.0' clock in the morning till late in the evening. The velocity of these winds begins to increase steadily from late March or early April when the average wind velocity is about 5 km/hr. and reaches its maximum in June when it is about 6 km/hr. The monthly average of wind velocity for three consecutive years i.e. 1974, 1975 and 1976 is given in table 4.

A peculiar phenomenon of the summer season is the occurrence of dust and thunder storms which are caused by the disturbance of the air current. They usually occur in the afternoon when the air movement is stagnant. Their frequency and strength increases with the advance of the season.

TABLE 3.

Mean monthly R.H. in % during 1974, 1975 and 1976.

Month	1974	1975	1976
January	62.5	73.3	68.0
February	51.9	59.6	63.5
March	43.3	58.5	46.4
April	27.7	28.2	32.2
May	33.8	28.4	63.1
June	40.5	56.9	51.2
July	71.1	74.3	76.8
August	78.8	80.3	82.7
September	59.3	63.3	67.7
October	53.0	62.9	47.9
November	48.3	53.2	56.4
December	62.5	60.2	58.5

TABLE 4.

Mean monthly wind velocity in Km. per hour (24 hours) during 1974, 1975 and 1976.

Month	1974	1975	1976
January	5.3	4.6	1.0
February	5.8	4.8	2.3
March	5.7	6.1	1.9
April	13.0	6.7	2.53
May	7.5	6.8	3.06
June	7.3	7.6	2.5
July	5.5	6.0	2.3
August	6.0	5.9	2.4
September	5.3	4.8	1.9
October	3.2	0.9	1.0
November	2.8	1.8	2.9
December	4.0	1.9	3.3

They are more frequent during May and early June. Sometimes they blow at a speed of 50-60 km./hr. These dusty storms are rarely accompanied by rains and, despite the blinding dust, they are welcome in the afternoon because of the lowering of the temperature. The air becomes cool and one gets temporary relief from the tiring heat of the day.

MATERIALS AND METHODS

Selection and Collection

For Extension Growth: Extension growth was studied in seedlings as well as in adult trees. For this purpose large number of seedlings were first raised in large earthen wares. Out of them, 100 were selected and transplanted after a month in 12 x 8" pots for weekly observations, taken in morning hours, on extension growth, leaf production, axillary branch formation and leaf-fall for one calendar year. To study the above in adult trees, 20 normal and healthy orchard trees of 20 years old were also selected and numbered serially. From each of these selected trees, 50 branches were tagged with alluminium foils for observation. The weekly data were collected and recorded in the following form for three calendar years 1974, 1975 and 1976:

Date _____

No. of tree _____

No. of branch	Total length of the branch (in inches)	Main or lateral branch	No. of leaves	No. of axillary buds	No. of floral buds	No. of flowers	No. of fruits	Remarks

For Radial Growth: To study the radial growth 40 normal trees of 20 years old were selected from local orchards. Cambial samples, together with some sapwood and bark of 1 inch square size, were collected from the main trunks at chest height (approximately at 1.5 meters from the ground) using a chisel and hammer at fortnightly intervals for a period of three consecutive years (1974, 1975, 1976). Four blocks were collected from each tree on each turn, covering all the four sides viz., East, West, North and South. Three trees were used for every turn and no samples were collected from the same tree before 3 months. Care was taken to collect the samples at least 10" away from the wounded spots, when the tree was used for the second or third time.

For Developmental Changes: To study the developmental changes in cambium and its derivatives, 5 trees of the same age (20 years old), comparable in vigour and size were selected. 20 samples of cambium with bark and wood were collected as described above, at different heights from the ground level from the same individual tree, covering the shoot axes of varying circumference. The same was repeated in all the five selected trees to compare the results.

For Shoot and Root Apices: The shoot apices from the adult trees and seedlings were collected, both from the main shoots as well as laterals to study their organization and activity

in different seasons. Similarly, root apices from the seedlings were collected to study their organization and tissue differentiation.

Axillary Buds: The axillary buds of different age and size were collected from current year shoots as well as from older shoots 2-4 years old.

Seedling Anatomy: Thirty to forty days old seedlings were uprooted and the shoot axis was cut into pieces of 1 cm and numbered serially from top to bottom. Similarly, the main roots and the laterals were also collected, pieced as above and numbered serially.

Periderm Development: Shoots of different age and bark samples were collected every 15 days to follow the time of initiation, and the mode of development of the first and the subsequent periderms in the shoot. Root samples from the seedlings were also collected to study the above aspects in the root.

Fixation: All the samples were fixed in F.A.A. or in Craf III solution. The axillary buds were carefully dissected in fixative in order to remove the brown leathery leaf-like scales and some of the young pairs of leaves, leaving in the

majority of cases a single pair of leaf primordia, which immediately covered the apical meristem. This operation facilitated the penetration of the fixative. All samples were aspirated in the fixative by the method prescribed by Johansen (1940) to remove the air,filled in the tissues, and to facilitate the easy penetratimn of the fixing fluid into the deep lying tissues.

Preservation: All materials were preserved in 70% ethanol. However, in a few cases, like barks and buds, one set was kept for 6-8 weeks in Alco-glycerol solution (equal parts of 50% glycerine and 50% ethanol) for softening.

Embedding in Paraffin: To study the developmental aspects, the materials were processed by the method of Jensen (1962) with some modifications for obtaining serial sections on a rotary microtome.

The sections were stained in different combinations of stain and mounted in Canada balsam after dehydrating in ethanol series.

To study the gross structure of the different organs and to follow the seasonal changes in structure, the materials were sectioned on a sliding microtome, at a thickness of 10-12/u in transverse, tangential longitudinal and radial longitudinal planes. The sections were stained in different combinations of stains and mounted in Canada balsam after dehydrating in ethanol series.

Stains Used: Following stains were used alone and in combination, depending on the purpose of the study:

(A) For the study of bark and wood:

1. Heidenhains Haematoxylin - Safranin (Johansen 1940).
2. Heidenhains Haematoxylin - Bismark brown (Johansen 1940).
3. Safranin - Crystal voilet - orange G (Johansen 1940).
4. Tannic acid - Ferric chloride - Lacmoid (Cheadle et al. 1953).

(B) For the study of cambium:

1. Heidenhains Haematoxylin.
2. Tannic acid - Ferric chloride (Foster 1934).

(C) For the study of shoot and root apices:

1. Safranin - Fast green.
2. Bismark brown - Fast green.
3. Heidenhains Haematoxylin - Safranin or Bismark brown (Johansen 1940).

In addition to the above, some other stains were also used for specific purposes:

1. Brom phenol blue for P-protein (Mazia et al. 1953).
2. Nigrosin for P-protein (Parker 1965).
3. Ponceau S for P-protein (Parker 1965).
4. 2% aquous iodine for starch.
5. 1% Astra blue for macerated sieve elements.

Leaf Morphology: Leaves of different ages ranging from primordial stage to fully matured size were collected and fixed. To study the venation pattern, distribution of sclereids and trichomes, young and matured leaves were cleared in NaOH solution (Ghouse 1973). The leaves were treated with NaOH solution at room temperature. Frequent changes of the reagent and provision of warm temperature (40°C) accelerated the clearing process. Within a period of 5-7 days, depending on the age of the leaf, the entire chlorophyll content of the leaves were drained off and they became transparent bodies. After staining in safranin they became suitable for studies.

To study the epidermal characteristics, peels were obtained of both the surfaces in their entirity or in pieces by giving the leaves a hot treatment with concentrated HNO_3 (40-50%) following the method described by Ghouse and Yunus (1972). The fixed material of leaves were washed in running water and trimmed to a suitable size before the treatment. The trimmed pieces were boiled in 40-50% concentrated HNO_3 till epidermal peels floated out as colourless papery structures. After cooling, they were washed, stained in Bismark brown or Haematoxylin, dehydrated in ethanol series and mounted in Canada balsam for studies.

For the isolation of epidermal peels and epidermis with trichomes out of young and delicate leaves, the double

treatment method described byLeelavati & Ramayya (1975) was followed. This method involved the treatment of leaf material and their segments with glacial acetic acid, followed by 5-6% NaOH solution and was found more suitable when the peels were required with intact epidermal hairs out of delicate leaves.

To follow the development of vascular elements and the other leaf tissues including the mucilagenous cavities, serial sections were obtained, using Spencer rotary microtome, out of the leaf materials varying in age and size from primordial stage to just open leaves with narrow lamina, embedded in paraffin, as described earlier. Serial sections of matured leaves were also prepared as above to study the leaf structure.

Leaf Abscission: To study the process of abscission in leaves, petioles of just turning leaves with their bases attached to the cortex of the shoot axis were collected, fixed in F.A.A., preserved in 70% ethanol, and sectioned serially after embedding in paraffin.

All leaf sections regarding developmental studies excluding the epidermal peels were stained with Haematoxylin and Safranin/Bismark brown or safranin and Fast green combinations and mounted in Canada balsam after passing them through ethanol series.

Maceration: To study the morphological details of the individual elements of bark and wood, pieces of them were macerated, using suitable reagents.

Phloem: For the isolation of sieve elements, sclereids and phloem parenchyma, bark materials were cut into thin tangential slices of .5 mm to 1 mm thickness. These slices were treated with 5% NaOH solution at 45-50°C. The treatment was continued till the cells of the slices became sufficiently loose to allow the separation of individual elements on a slide with a slight pressure when applied over the cover slip after mounting in 5% glycerin (Ghouse et al. 1974). When the desired stage had been reached, the slices were washed and stained in Astra blue (1% aquous solution) or aquous laemoid solution of 2% (both for sieve elements). In case of phloem and sclereids the material was treated with safranin.

Xylem: To study the morphological details of vessels and fibres, the wood pieces were treated with concentrated HNO_3 and Potassium chlorate, following the method described by Ghouse & Yunus (1972) after some modifications. The partially macerated slices were stained in Haematoxylin/Saf-ranin/Bismark brown, dehydrated and mounted in Canada balsam. The different elements were separated by mechanical means using a pair of needles before mounting or applying pressure over the cover slip after mounting.

For Starch Detection: To study the seasonal fluctuation in the starch contents of cambial cells and its derivative tissues (Phloem and xylem) fresh materials (unfixed) were used. They were sectioned on sliding microtome at the thickness of 20-25/u in transverse, tangential and radial longitudinal planes. The sections were treated with 2% aquous Potassium iodide solution.

Measurements: The size of the different elements was measured under specific magnifications of the microscope, using micrometer scale.

Quantitative Estimation of the Tissues: The proportional distribution of different types of elements in transections and tangential longitudinal sections was determined on the basis of the area occupied by the respective elements. This was calculated by the methods described by Ghouse and Iqbal (1975). The first was based on the weight of paper cuttings of drawings of different elements made with the aid of camera lucida, on tracing papers. The portions bearing the drawings of the desired elements were first removed and weighed. Then the portions containing the figures of the other elements were weighed. The ratio of one type of element with respect to others in a unit area was then calculated. The efficacy of the above method was tested by actual measurements of the elements.

Abreviations: Symbols A, B, C, D ..... J are used in the histograms to indicate the various circumferences (cm) of the axis -- A = 1, B = 2, C = 10, D = 30, E = 72, F = 92, G = 108, H = 140, I = 184 and J = 192.

EXTENSION GROWTH

For the study of extension growth 20 healthy normal trees were selected. From each tree about 50 branches were selected for observation and tagged with aluminium foils. Extension growth of the shoots, lateral branch formation, floral bud production and leaf fall were noted at fortnightly intervals for three consecutive years (1974, 1975, 1976). It was noted in 1974, that in January and February most of the branches remained dormant, and in March they showed bursting of apical buds, the formation of new leaves and branches. The shoots reached their peak growth in April. In May and June the growth slowed down to a considerable extent. Again, in July the rate of extension growth went high to reach its peak. The elongation growth continued to occur till the end of October. In November most of the branches remained inactive and continued to remain so till next February.

In 1975, the data were collected on the same lines as in 1974. The results obtained in 1975 showed slight deviations from that of 1974. In the month of February the initiation of extension growth was noted which acquired a rapid rate in April as in the previous year. This was followed by a sharp fall in the rate of growth in May and June. In July the rate of extension of growth again became rapid as in April which was

again followed by a sharp fall in September as it happened in May and June. In October 1975, most of the branches became inactive and showed no length increment in the following months till February 1976. The mode of growth of these branches thus appeared to have experienced two apparent flushes of extension growth - the first from February to April and the second in July and August - but, in reality, they did not experience two flushes of growth as they continued to grow from February to September continously but at different rates with two maxima in their rate of growth, viz., the first in April and the second in July.

In 1976 the pattern of extension growth initially followed the same trend as in 1975, but in July the rate of growth went high to reach almost the maximum in most of the branches. In August the rate rapidly fell in a majority of the cases while in some the high rate was maintained till August. However, in all the cases the growth rate became considerably slow in September and stopped completely in the late October.

In general, the extension growth began in late February or in early March and ended in October. The rate of growth became rapid twice in a year, depending on the environmental conditions. In 1974 the growth started late as compared to 1975 and 1976, but attained the maximum in April as in the other years. The second high rate of growth occurred in all the three years after the beginning of monsoon.

However, in 1975 the maximum growth of shoots occurred in August instead of July, that is, a month late due to the late monsoon in this year. In all the three years the shoots remained dormant for about three to four months that is from November to February or March (Fig. 4).

Formation of new leaves: New leaves were added throughout the period of extension growth which ran about 8 months in a year. There appeared to be no sharp duration of leaf production. Since the guava is an evergreen tree, the leaf formation and leaf fall went together during several months. The leaf fall started from February, continued upto May, while the leaf production started from March and continued upto September. By April and May, almost all old leaves fell, while a few new ones were added at the top. The leaf fall occurred in acropetal order i.e., the oldest leaves fell first, while youngest in the last. The total number of leaves in a tree when counted in 1974, at fortnightly intervals, had shown that the trees were rich in leaves for about seven months i.e., from July to January, while in the other five months i.e., from February to June, they were poor in leaves. More or less, the same results were obtained in the subsequent years i.e., in 1975 and 1976 (Fig. 5).

Formation of axillary branches: With the production of new leaves, new axillary buds arose, to give rise to lateral

branches. Most of these branches formed dwarf shoots with a limited amount of growth. These branches developed floral buds, after giving rise to a few pairs of leaves. With the ripening of the fruits, most of these branches dried and fell off from the tree and, therefore, the number of lateral branches particularly the dwarf or fruit bearing shoots differed significantly in the different seasons. The observations on the formation and the total number of such branches on selected trees round the year for three calendar years had shown that the number goes high twice in a year.

Floral bud production: Production of floral buds was studied for three calendar years (1974, 1975, 1976) on selected trees. For this purpose about 500 branches were tagged on ten trees at the rate of 50 per tree. It was noted that the flowering occurred mostly on dwarf shoots and rarely on main shoots. In the first year of the observation i.e., 1974, the flowering was noted in the middle of March to initiate and reached its maximum in April (Ambe-bahar). In May almost the process stopped with the exception of a few branches in which the flowering occurred sporadically. This was the first crop of the season and fruits ripened in the rainy season i.e., July to September.

The second flush of flowers initiated in July continued upto September with the maximum occurring in August. The rate of flower production fell abruptly in September (Mrig-bahar).

In the majority of the cases, the flower production ceased in September while in a few 1 or 2 flowers did appear even in this month. From October to the middle of March next, no flowering was noted in any of the 500 branches tagged in all the three years of observations. The fruits developing out of this second flush of flowers ripend from December to February.

More or less, similar results were obtained in the subsequent years i.e., 1975 and 1976 with minor variations (Fig. 5).

Extension growth in seedlings: About 100 seedlings were selected and transplanted in pots of 12 x 8" at the rate of 1 seedling per pot. The observations were recorded under natural conditions for one full year, starting from November to October next. It was noted that extension growth of the main axis initiated in February and continued upto October without any apparent break. The new leaf production initiated in February, continued upto October along with the elongation of the axis without any break in the production of leaves (Fig. 6).

APICAL MERISTEM

The shoots as well as roots bore a group of meristematic cells on their distal ends - the apical meristem. The vegetative shoot apex of this plant was found narrow and conical in form, partly closed by the oppositely developing leaf primordia (Plate 1). The width of the apical meristem close to the first pair of leaf primordia measured from 55-170/u and the height from 35-90/u. The shape and size exhibited variations during the course of development of leaf primordia.

In a median longitudinal section of the shoot apex of this species the surface cells formed a regular mantle (the tunica) which showed only anticlinal divisions. The cells situated below the tunica, (the corpus) were less regularly arranged and showed divisions in all planes i.e., periclinal, anticlinal and oblique. The tunica was single layered and remained the same throughout the life of the plant (Plate III).

Histological studies of the shoot apex revealed the cyto-histologic zonations. Three cyto-histologic zones were observed viz.,(1) the distal zone comprising of 6-7 layers with cells having comparatively large nuclei and dense cytoplasm; (2) the proximal zone, located below the distal one comprising the cells with comparatively small nuclei and large vacuoles

and (3) the peripheral zone composed of 5-6 layers of cells characterised with comparatively small nuclei and small vacuoles. The peripheral zone stained higher than the distal zone but darker than the proximal zone.

The leaf primordium, the procambium, the dermatogen and cortical ground tissues were produced by the periperhal zone in this species. The proximal zone differentiated into the vacuolated pith cells. The distal zone (a combination of tunica and corpus cells) actually consisted of the initials and their most recent derivatives.

Leaf initiation: The leaf primordia were initiated by periclinal divisions in the corpus cells of the peripheral zone at about 50/u away from the apex. This was followed by anticlinal divisions in the surface cells of peripheral zone i.e., in the tunica cells. The divisions initiating a leaf primordium caused the formation of lateral prominance which later developed into leaf buttresses, and thus both the tunica and corpus participated in the formation of leaf primordia in this plant. The leaf primordium in the initial stages of growth showed somewhat flattened adaxial side and two laterally placed meristematic groups of cells which formed the blades later. The tunica formed the epidermal tissue, while corpus contributed the formation of mesophyll and vascular tissues.

Vascular differentiation into a developing leaf, began with the differentiation of future midvein by the development

of procambium in continuity with the procambium of the axis (Plate III). The phloem differentiation preceded the xylem. The lateral veins of various orders originated in the mesophyll.

The whole process of leaf development, i.e., from the level of visible initiation to expansion took about two weeks in this species.

Order of appearance of the first phloem and xylem elements in the apex of the shoot: The differentiation of the vascular tissues of the shoot was closely connected with the development of leaves. The first differentiated vascular elements of the stem, appeared in localized regions and constituted the leaf traces. The first sieve-tube within the stem appeared about 300/u and xylem elements about 550/u below the growing point. After the formation of a few sieve-tubes, a xylem element developed. Later, more sieve-tubes were produced on the right and left of the first sieve-tube and ultimately they formed a group on the outer side (abaxial) while more tracheary elements were produced on the inner side (adaxial) of the procambial strand (Plate IV).

The first sieve-tube element of the cauline bundles appeared on the lateral sides of the axis and gradually a discontinuous cylinder of sieve-tubes and tracheary elements was produced out of the procambial strips. The cells of the procambium showed radial seriation in older regions and therefore

the vascular tissue, both primary phloem and xylem produced at a later stage, were found in radial allignment (Plate V). The continuity of the vascular cylinder was interrupted by parenchyma cells, produced by some of the procambial cells, which, in their course of development, exhibited expansion in size and irregular divisions (Plate V).

Each procambial cell possessed distinct and large nucleus. In tangential view the procambial cells appeared slightly elongated with transverse end walls (Plate IV). The proto-xylem element developed spiral thickenings while the metaxylem scalariform on their lateral walls. The protophloem elements generally lacked distinct companion cells and became obliterated in the early stages of development of the organ (Plate V).

In the part of the stem which had ceased to elongate the procambium transformed into vascular cambium, which, in its due course, gave rise to secondary vascular tissues (Plates III, V).

The groups of internal phloem differentiated on the periphery of the pith, adjacent to the proto-xylem elements and in the older shoots were arranged in a ring (Plate V). They were crushed together with the pith parenchyma in the older regions of the shoots.

PRIMARY STRUCTURE OF THE SHOOT

Shoot axis at its primary stage looked quadrangular and green in colour, bearing a large number of unicellular trichomes and multicellular secretory appendages arranged in a row in the axils of leaves. These appendages probably helped in the protection of axillary meristem (Plate II).

The apical and the axillary buds, the different parts and photosynthetic leaves bore large number of unicellular trichomes which grew out from the epidermal cells and provided protection while they were young, delicate and tender. Presence of these hairs troubled the embedding of buds, young shoot tops and floral organs in wax for serial sectioning.

A transection of a young shoot through the internode revealed a quadrangular outline with four prominently projected ridges. The entire periphery including the projected arms was enclosed in a uniseriate epidermis. The vascular system formed almost a continuous cylinder and appeared embedded in the ground tissue. A continuous cylinder of vascular cambium developed between the primary phloem and xylem. The vascular strands were so closely arranged to leave only narrow interfascicular regions which were not easily visible under low magnification. The vascularization appeared, therefore, in the form of a continuous cylinder. The vascular cylinder

was hallow and enclosed a mass of parenchyma cells which constituted the pith. The ground tissue situated between the epidermis and vascular system constituted the cortex which consisted of 7-11 layers of parenchyma cells with an average of 9 layers. Groups of internal phloem developed on the periphery of the pith. No distinct endodermis was present either interior to inner phloem or outer to external phloem in the shoot of this species (Plate VI).

Mature epidermal cells of the shoot were tabular in shape because of their relatively small extent in depth. In surface view, they looked elongated, arranged compactly and covered with a thick layer of cuticle. The plastids in the epidermal cells were not well developed, but in the younger regions some differentiated into chloroplasts. The cell walls of epidermis were evenly thickened and did not undergo lignification even in older regions. Occasionally stomata developed in the younger regions of the shoot.

The cortex made up of thin walled parenchyma cells, formed a continuous enclosure over the vascular cylinder and extended into the ridges at the periphery. The cortical cells developed intercellular spaces throughout the cortical region. Interior to the cortex there were a few layers of thick walled but small parenchyma cells which separated the cortex from the stele and constituted the pericyclic zone (Plate VI).

The pith, in a young stem, was narrow and parenchymatous. Some of the pith and cortical cells later differentiated

into brachysclereids at nodes.

The anatomy of a node differed from that of an internode in a number of ways including the arrangement of vascular tissues. The nodal vascular system looked complicated due to the divergence of vascular strands to the leaves and axillary shoots. The cortical and pith cells were slightly shorter in the nodes than in the internodes. A transection through nodal region revealed two opposite gaps in the vascular cylinder occupied by parenchyma cells. The vascular supply to leaf bases came from the main cylinder and appeared like two parallelly running strips in transections (Plate VII). Each node bore two oppositely situated axillary meristems or sometimes condensed shoots with their own apical meristems and laterally placed leaf primordia (Plate VIII). These dormant shoots finally grew out into axillary branches. But at the flowering season, some of these arrested bodies emerged out as reproductive buds. The details of the transformation from vegetative to reproductive phase were not worked out in the present study. Generally, some of the pith and cortical parenchyma formed sclereids whose number concentrated mainly at the leaf gaps and in the centre of the pith. This localisation of sclereids in the nodal regions might be presumed as an additional device for mechanical support to bear the load of the various organs borne on nodes. The sclereids found in the nodal regions were of brachy-type

irregular in shape and size, bearing thick lamellated secondary walls with ramified pit canals (Plate VII).

The peripheral cells of the primary cortex of this species developed ducts of varying size below the epidermis including in the projecting arms of the young shoots. These ducts were secretory in nature, contained chemical deposits and arose through the dissolution of cortical cells. The remnants of broken cell walls sometimes remained attached to the periphery of the ducts. In the primordial cells of these ducts the secretory substances accumulated before their breakdown. The breakdown occurred in a few cells to start with and then extended to neighbouring cells. As a result of the above, a big duct developed between the cortical parenchyma cells. No distinct epithelial layer of cells developed around these ducts (Plate IX). The development of these ducts remained strictly restricted to the primary body of the plant.

The secretory ducts had only a short life as they developed only in the primary tissues. They did not develop in the secondary body of the plant. The width of these ducts measured from 56-150 μ while their length varied from 80-225 μ.

Developmental changes in the shoot: A transection of about 3 months-old shoot through the internodes of this species showed a continuous ring of xylem surrounded on both sides by phloem. Between the outer phloem and xylem a continuous ring of cambium was seen.

The outer phloem consisted of groups of phloem elements separated by large parenchyma cells. These groups consisted of sieve-tubes, companion cells and axial parenchyma. The arrangement of large parenchyma cells resembled the rays (Plate V). These might be called as 'Primary ray cells'.

On the periphery of the phloem in older shoots, a continuous cylinder made-up of 2-3 layers of thick walled parenchyma cells developed. They appeared to have originated out of the pericycle. Widening of this zone at a later stage occurred due to frequent periclinal, anticlinal and oblique divisions in the existing cells (Plate VI). The outer-most cells of this zone developed into fibres and at a later stage a discontinuous fibre ring developed which separated the primary cortex from thick walled parenchymatous cylinder (Plate VI).

The sclerenchymatous fibres were elongated generally, having pointed ends. They developed thick lignified secondary walls which were made up of cellulose fibrils in concentric layers and showed simple pits. The lumen size varied from cell to cell. The fibre length varied from 140-520/u with an average of 295/u.

The internal phloem was in radially elongated groups, separated from one another by the extensions of pith parenchyma cells and it formed a discontinuous cylinder around the pith. The internal phloem consisted of distinct sieve tubes and companion cells (Plate V).

Secondary growth in shoots: The vascular cambium arose in the form of a cylinder between the primary xylem and phloem by the transformation of procambial cells and remained in the same relative position indefinitely, producing secondary xylem towards the inner and the secondary phloem towards the outer sides.

The production of secondary elements by the newly formed vascular cambium affected the primary tissues in various ways. The primary phloem was pushed out which led to the complete destruction of the primary sieve elements. The primary xylem was, in a similar way, pushed towards the pith and finally crushed. The primary cortex, together with the epidermis and the sclerenchymatous fibres, were peeled off later after the periderm formation.

In a transection, the amount of xylem was found much more than the phloem as a result of unequal production of the two types of tissues by the vascular cambium. The amount of the internal phloem and the entire pith were completely crushed later in the older axis and looked like a black streak, running parallel to the axis, in the centre of the xylem cylinder.

PRIMARY STRUCTURE OF ROOT

The root constituted the underground part of the plant axis acting as an absorbing and anchoring organ. The apical meristem of root remained covered and protected by a multicellular root cap.

The cells of the root cap were living parenchyma cells and a mucilagenous wall occurred between the root cap and protoderm. A transection of root (primary) showed a homogenous parenchymatous cortex having 9-12 layers of parenchyma cells with an average of 10. The cortical cells were arranged in successive concentric layers with well-developed inter-cellular spaces which arose in the early ontogeny of the root. The inner-most layer of the cortical parenchyma differentiated into the endodermis. Interior to endodermis were a few layers of parenchyma cells which formed the pericycle.

Near the root tip the cortex constituted only a few layers of cells. Repeated periclinal divisions in these cells made the cortex wider, while the anticlinal divisions increased the circumference. The outer cortical cells were bigger than the inner ones. The endodermis was not much differentiated in this species, as the characteristic casparian

strips did not develop on these cells. In the centre, there was a narrow parenchymatous pith around which the vascular tissues were placed. The pericycle and endodermis separated the vascular tissues from the cortex. The xylem was exarch; as the elements differentiated in the centripetal direction. The phloem, too, differentiated centripetally. The sieve tube members of protophloem which differentiated on the periphery did not possess distinct companion cells, while the metaphloem elements were associated with well defined companion cells. The four exarch xylem groups were found alternately arranged with four phloem groups and both types of vascular strands looked embedded in the ground tissue i.e., pith parenchyma (Plate X).

The pith parenchyma cells exhibited a compact arrangement and their walls were slightly thick as compared to that of cortical parenchyma.

The lateral roots were found arising opposite to protoxylem arms from the pericycle. During the initiation of a lateral root, several contigous pericyclic cells divided periclinally and anticlinally. The accumulating cells formed a protrusion, the root primordium. As the root primordium showed an increase in size, it penetrated the cortex and ultimately came out after breaking the epiblema. The endodermis and the other cortical cells appeared to be partly deformed, crushed, pushed aside and even partly dissolved in front of the advancing tip. During

the growth of a lateral root primordium, through the cortex, the promeristem and root cap were initiated (Plate XII).

The phloem and xylem elements of the lateral roots became connected with the equivalent elements in the parent root. The cells lying at the proximal end of the lateral root primordium differentiated into vascular elements. The laterals also arose from the older regions of the root and followed the above mentioned process of growth.

Secondary growth in roots: Below the phloem strands the procambial elements differentiated into cambial strips (Plate X). As these cambial strips added some secondary elements, the cells situated adjacent to the prtoxylem cores (pericyclic cells) also became meristematic and joined laterally with the cambial strips to complete the ring of cambium in young roots. The cambial ring so formed was wavy in appearance at this stage (Plate X). Due to unequal activity i.e., being more active between the xylem arms than opposite to them, the cambium assumed a cyclic appearance (Plate X).

The sieve elements of the protophloem soon got obliterated which was followed by metaphloem; later the whole of the primary phloem disappeared as the secondary elements were produced by the activity of newly formed lateral meristem. Secondary vascular elements were continuously added on either side of the vascular cambium which retained its meristematic potentialities throughout the life of the plant, provided the root remained undamaged.

Periderm development in the growing shoots: The periderm development took place in acropetal order. The phellogen initial arose in the pericycle, just below the fiber ring (Plate IX). At first, the periclinal divisions occurred at localized areas around the stem, but generally below the ridges. Subsequently, meristematic activity slowly spreaded in tangential directions and finally formed a continuous ring at the periphery of the stele (Plate IX).

The first periclinal division in the phellogen mother cells resulted in two apparently similar daughter-cells. The outer daughter-cell first underwent enlargement in radial direction and divided periclinally to form a first phellem layer towards the periphery and the phellogen proper towards the innerside (Plate IX). The inner daughter-cell of the first periclinal division normally remained in the same size or occasionally underwent a little expansion in tangential plane to form the first phelloderm layer. Further divisions in periclinal plane in the phellogen added more phellem layers towards the periphery and phelloderm towards the inner side (Plate IX). The first formed phellem developed suberine deposition in the form of tangential bands and remained distinct from the rest, since the later forming phellem cells remained more compressed radially than the earlier formed ones.

The phellogen kept space with the increase in the stem circumference by periodically undergoing radial auctidinal divisions.

The phelloderm consisted of layers of living cells. Some of these cells enclosed one or two large crystals in their lumen. In the following years subsequent periderm developed in successively deeper layers out of the phloem parenchyma cells (Plate IX).

However, the phellogen thus formed subsequently did not form a continuous ring as the first phellogen. New phellogen formation occurred every year as the previous phellogen became inactive and got peeled off. (Plate II).

Lenticels: The lenticels in Psidium guajava were of small size and found slightly protruded above the surface. Their size varied from 31 to 300/u in width. They developed from the phellogen of the periderm. The phellogen in the localized region started producing filling tissues in place of phellem cells. The filling tissue in this species exhibited compactly arranged suberzied cells. At the base of filling tissue developed a layer of lignified cork cells, which may be named as closing layer (Plate XV).

Periderm development in roots: The formation of periderm in roots followed the same pattern as in the shoot. However, the phellogen, once formed, continued to function as long as the root existed (Plate XI).

STRUCTURE OF MATURE LEAF

In Psidium guajava leaves were simple, having a short petiole. The expanded blade size in average measured 4-10 x 3-4.5 cm. The leaves were reticulately veined. The vascular bundles of various dimension formed a net work, the smaller bundles diverging from the larger. The largest vein represented the mid-vein and the somewhat smaller veins diverged from it laterally.

A transection of leaf passing through the midrib of this species exhibited a single arch-shaped bicollateral vascular strand surrounded by thick walled parenchyma cells, rich in tanniferous deposits. Abaxial to the vascular strand, but out/-er to the parenchymatous sheath, two big groups of scherenchymatous fibers developed on either side. On the adaxial phase, a slightly big patch of fibres developed in a median position, which ran parallel to the mid-vein (Plate XIII). The phloem formed a continuous strip on the abaxial as well as on the adaxial phases of the vascular strand. Between the abaxial phloem and the adaxial xylem, there was a well-defined vascular cambium which added some secondary vascular tissues to the mid-vein in due course of time. However, no cambium developed between the adaxial phloem and xylem (Plate XIII).

Major laterals were similar in structure as the mid-rib in having bicollateral condition and a foliar cambium. While the minor veins and the veinlets differed in their constitution from the major ones. They were simply made up of a few elements of xylem, mostly with spiral thickening, a few sieve elements placed on the abaxial side and supported by a few fibre elements.

Mesophyll: The mesophyll consisted of living parenchyma cells containing abundant chloroplasts particularly in blades. The mesophyll was heterogenous and differentiated into palisade and spongy parenchyma. The palisade tissue consisted of 2-3 layers of cells, elongated at right angle to the epidermis and arranged compactly in rows particularly in the blades. Spongy parenchyma consisted of about 4 layers of cells, arranged loosely with intercellular spaces. At times they also assumed palisade-like elongated shape but did not get arranged so compactly as the real palisade layers.

Hypodermis: A distinct, continuous, hypodermis developed below the upper epidermis consisting of 2-3 layers of thick walled cells, somewhat larger in size than the mesophyll and epidermal cells. Its amount varied from place to place in the same section.

Mucilagenous cavities of varying size were found in the mesophyll below the epidermis. They developed more

abundantly on the abaxial side. They were of lysogenous nature without epithelial parenchyma and contained mucilage. They continued to enlarge, involving more and more lysis of the adjacent cells and therefore in the same leaf one found ducts of varying dimensions and developmental stages. The larger ones included less mucilage than the small and younger cavities. They appeared to develop at random basis than in any regular pattern. The development of these cavities took place very early in the ontogeny of the leaf, even before the cambium formation. New cavities continued to form even in the matured leaf.

Epidermis: The leaf epidermis consisted of ordinary ground cells and some specialized cells like guard cells, subsidiary cells and trichomes. The ground cells exhibited a compact organization except the places of stomata. Thick depositions of cuticle took place on the outer surface of these cells. Their anticlinal and periclinal walls ran straight. They appeared in surface view as elongated bodies. They were modified to form elongated elements with almost transverse or slightly oblique end walls below the veins.

Their size varied from 11-38/u in length and from 8-15/u in width on the abaxial surface while from 19-57/u in length and from 11-30/u in width on the adaxial surface. Along the veins their length and width again varied in both the surfaces of the leaf. They varied in length from 25-83/u

and in width from 4-15/u on the abaxial surface, while from 15-79/u in length and from 8-15/u in width on the adaxial surface (Table 5).

Among the specialised cells of the epidermis, trichomes formed one of the prominent structures. They were unicellular and vermishaped with spiny distal ends, more frequent on the abaxial surface. They were randomly distributed on both the surfaces of the leaf in a uniform manner. They measured about 107/u in average length and 10/u in width near the base (Table 5).

Stomata occurred on the abaxial surface. They were uniformly distributed all over the abaxial surface, with their pores directed in all directions. In the majority of the cases the subsidiary cells were two in number, orientated parallel to the guard cells - paracytic type, while in a few, both the number as well as the orientation of the subsidiary cells deviated from the normal. The guard cells in average measured 15/u in length and 5/u in width, while the aperture in fully opened conditions measured from 7 x 5/u. The size of subsidiary cells closely followed the guard cells.

Development of stomata: Stomata arose through differential divisions in the protoderm. After several divisions of a protodermal cell, one of the product of these divisions became immediate precursor of the guard cells. This acted as the stoma or guard cell mother-cell which eventually

TABLE 5.

Diamensional data on leaf epidermis of Psidium guajava.
Figures within parentheses indicate the range.

Cell types	Abaxial side		Adaxial side	
	Length in /u	Width in /u	Length in /u	Width in /u
Trichomes	101 (41--196)	12 (8--16)	113 (38--160)	8 (4--11)
Midrib cells	36 (15--79)	9 (8--15)	52 (25--83)	9 (4--15)
Ground cells	20 (11--38)	10 (8--15)	39 (19--57)	21 (11--30)
Guard cells	15 (11--23)	6 (4--8)	-	-
Subsidiary cells	16 (11--23)	3 (4--5)	-	-
Stomatal aperture	7 (4--11)	5 (4--8)	-	-

divided into two guard cells. These enlarged and assumed the characteristic crescent shape. The area of the future stomatal pore showed lenticular mass of pectic material which resulted from the swelling of the intercellular material preceding its dissolution. The guard cells and subsidiary cells occurred at the same level as the adjacent epidermal cells.

Development of trichomes: The trichomes were initiated as a protuberance from epidermal cells. The protuberance elongated and developed into a unicellular trichome. The walls of trichomes were made up of cellulose and remained covered by cuticle. Foliar trichomes generally developed spiny pointed ends, while the trichomes developing on other organs had blunt ends.

Structure of petiole: Transections passing through the petiole of a mature leaf exhibited a single arch-shaped vascular strand, which was wide open with somewhat incurved ends, placed in the median position. The vascular strand was bicollateral with well-defined abaxial and adaxial phloem. The whole vascular strand was embedded in ground tissue which was made up of thick walled parenchyma cells. However, a few layers of cells immediately surrounding the vascular strand were thick walled in which crystals of various types

and deposits of tanniferous substances were frequently noted. These layers of cells developed out of the provascular tissues rather than the cortical ones and formed distinct sheath like structure around the vascular strand. A few sclerenchymatous idioblasts were also found in the ground tissue occurring in a scattered manner. Mucilangenous cavities of lysigenous nature with or without depositions occurred mostly below the epidermis and at times at deeper layers of the ground tissue. There was no hypodermis differentiation in the petiole. The epidermis was represented by a single layer of cells whose outer tangential walls accumulated thick layers of cuticle (Plate XIII).

Anatomical studies of petiole structure in leaves of varying age and size had revealed the presence of a well-developed vascular cambium between the abaxial phloem and the xylem. The cambium, together with its un-differentiated derivatives at times, formed a wide zone of cells consisting of as many as 3-5 layers. The tangential longitudinal sections, passing through this cambial zone had defined the nature of this foliar cambium in having the fusiform initials forming the axial system and the ray initials representing the horizontal system of the secondary body (Plate XIII). The activity of this foliar cambium appeared to have added fairly good amount of secondary elements which replaced the primary ones, partly, if not totally.

Leaf abscission: The separation of a leaf from a branch, without injury to the branch, was called leaf abscission. In P. guajava abscission occurred near the base of the petiole, by cytologic and chemical changes in cells along which the leaf separates and this was called as abscission zone. Two layers of cells differentiated in this zone - an abscission, or separation layer, and a protective layer. The protective layer occurred beneath the separation layer and protected the surface which became exposed when the leaf fell off. The separation of leaf occurred due to the dissolution of primary wall in addition to the middle lamella. This was initiated in the ground tissue. The vascular strands were broken mechanically at the end of the process of separation.

The protective layer was formed through the deposition of suberin. The protective layer was replaced later by the periderm which developed below the protective layer.

VASCULAR CAMBIUM

The vascular cambium which was non-stratified formed a complete cylinder around the xylem in stem and roots of this species. It was made up of two types of initials viz., cells with parallel laterals and tapering ends, the fusiform initials and nearly isodiametric, relatively small, the ray initials (Plate XX). The fusiform initials were highly vacuolated while the ray initials were generally found containing varying degrees of tanniferous substances and starch, depending on the season. Ray initials accumulated tannin while the fusiform initials were free from such substances. The accumulation of tannins took place to their maximum in April and May while they were totally absent in July to September. In the other months they were found only poorly (Plate XXIII). Similar observation on the starch contents of the initials showed that starch accumulated in September and remained intact upto January in both the types of initials, while in the other months test for starch yielded negative result in both the types of initials (Table 6). The walls of fusiform initials bore primary pit-fields and showed distinct plasmodesmata connections with contiguous elements, particularly with the ray initials. The radial walls of these elements were

TABLE 6.

Seasonal variations in the amount of starch and tannins in ray and fusiform initials.

Months	TANNINS		STARCH	
	Ray initials	Fusiform initials	Ray initials	Fusiform initials
January	+	-	+	+
February	+	-	-	-
March	++	-	-	-
April	+++	-	-	-
May	+++	-	-	-
June	++	-	-	-
July	-	-	-	-
August	-	-	-	-
September	-	-	+	+
October	+	-	+	+
November	+	-	+	+
December	+	-	+	+

\- = Absent
\+ = Poor
++ = Moderate
+++ = Rich.

comparatively thicker than the tangential ones and appeared beaded, especially during dormancy (Plate XXIII).

A number of fusiform initials showed more than one nucleus. In some extreme cases the nuclear number went as high as five in one cell. Although the number of nuclei varied from 1-5, the majority of the initials had 1-3 (Plate XXI). A detailed study on nuclear condition of fusiform cambial initials in samples collected at fortnightly intervals round the year had shown that the polynucleated condition was partly influenced by prevailing weather conditions. The nuclear number in the initials increased during the dormant period (November-January) while it decreased during the active phase (Table 7).

In a multinucleated initial, the nuclei took various shapes - spherical, spindle, tailed (Plate XXI) and their shape varied not only in different elements but also within an element. The table 8 shows the variation in nuclear number of the initials in different seasons.

In a cell, only a few nuclei (1-18%) showed the sign of degeneration, although the majority of them assumed abnormal shape and possessed intact nuclear membrane and nucleolus (Table 9). In the degenerating nuclei, the nuclear contents got degenerated first, followed by the degeneration of the nuclear membrane. However, in some cases the spherical nucleus first became spindle-shaped due to elongation, the ends of which

TABLE 7.

Seasonal variations in nuclear number of fusiform cambial initials of *Psidium guajava*.

Months	Percentage of nuclei				
	Uni-nucleate	Bi-nucleate	Tri-nucleate	Tetra-nucleate	Penta-nucleate
January	16	36	32	12	4
February	32	36	28	4	-
March	36	32	28	4	-
April	28	52	20	-	-
May	36	44	12	8	-
June	32	48	12	8	-
July	36	32	24	8	-
August	40	36	20	4	-
September	30	32	28	10	-
October	36	44	20	-	-
November	12	20	40	20	8
December	12	48	24	12	4

TABLE 8.

Seasonal variations in the shape of nuclei of fusiform initials in Psidium guajava.

Months	Percentage			
	Spherical	Elongated	Tented	Degenerating
January	29	45	21	5
February	27	24	31	18
March	14	33	39	14
April	21	29	44	6
May	43	35	16	6
June	15	47	31	7
July	40	39	7	14
August	19	30	45	6
September	38	44	15	3
October	9	41	46	4
November	11	38	49	2
December	31	56	10	3

TABLE 9.

Seasonal variations in the structure of nuclear membrane of the nuclei of fusiform initials of Paidium guaiava.

Months	Percentage	
	Nuclear membrane present	Nuclear membrane absent
January	92	8
February	64	36
March	96	4
April	100	-
May	96	4
June	95	4
July	96	4
August	100	-
September	100	-
October	100	-
November	100	-
December	96	4

became thread-like, forming tail-like structures, ultimately leading to the complete degeneration, starting from the tailed ends (Plate XXI).

The fusiform initials underwent periclinal divisions - additive divisions (Bannan 1956), in order to give rise to outer and inner derivatives which eventually differentiated into xylem and phloem elements respectively (Plate XXIV). They also underwent pseudo-transverse anticlinal divisions (Plate XXIII) in order to multiply their own number and thus enable the cylinder to expand with the expanding trunk of the tree - the multiplicative divisions (Bannan 1956). The anticlinal walls appeared in a dividing cell at various degrees of inclination. After such a division the daughter cells underwent apical elongation as a result, the two sister cells came to lie lateral to each other in tangential plane. Depending on the degree of elongation, the elements possessed long to short tapering ends which ranged from 105-192/u, while the whole fusiform initial including the tapering ends measured from 308-423/u in an adult tree. The width of these elements also varied from element to element and ranged from 14-19/u. Both the length as well as the width appeared to have been influenced by the prevailing weather conditions. Table 10 indicates their variation under different seasonal conditions.

TABLE 10.

Changes in cell size of fusiform initials (as observed in tangential sections) of cambial zone in Psidium guajava during 1974. Values within parentheses indicate the range.

Months	Mean length in /u	Mean width in /u	Size of gabled end in /u
January	347 (263--431)	15 (11--23)	139 (49--218)
February	399 (263--439)	17 (15--23)	113 (56--195)
March	371 (229--570)	18 (15--26)	124 (56--255)
April	308 (225-450)	18 (11--23)	124 (49--210)
May	332 (263--469)	18 (11--23)	146 (75--236)
June	380 (263--469)	17 (15--26)	125 (37--195)
July	398 (263--525)	14 (11--19)	192 (75--225)
August	342 (229--431)	19 (11--22)	105 (34--263)
September	332 (188--431)	18 (11--23)	105 (23--169)
October	350 (281--431)	19 (15--23)	134 (14--225)
November	381 (318--487)	19 (11--23)	105 (34--180)
December	423 (337--480)	18 (15--22)	110 (53--210)

The ray initials of varying size and shape aggregated themselves to form fusiform ray initial units. These initials as they were different in shape and size formed heterogenous units which varied in height from 1-36 cells to 1-5 cells in width. Their periclinal and anticlinal diameter varied from 27/55 to 8/13/u (Table 11). In one and the same section one could find ray initial units of uniseriate to multiseriate nature as well as units of varying heights (Plate XX). The occurrence of different ray initial units with respect to their height and width, when studied in fortnightly collections of three consecutive calendar years had revealed that the size as well as their formation and development of these ray initial units happened to be highly influenced by the seasonal effect (Tables 12, 13). The uniseriate and short rays were more frequent in August, September, November and December while the long and broad multiseriate units were found frequent in other months (Plate XX).

Structural variation during 1975 and 1976: Similar studies on cambial structure were repeated during 1975 and 1976. The results obtained are depicted in tables 14-17 and 18-21 respectively which almost tally with the findings of the year 1974 as described earlier.

Formation of new ray initials: The new ray initials were produced out of fusiform initials. This happened by transverse

TABLE 11.

Changes in the cell size of ray initials in the cambial zone of Psidium guajava during 1974. Values within parentheses indicate the range.

Months	Ray initial elements	
	Periclinal diameter in /u	Anticlinal diameter in /u
January	36 (11--56)	13 (8--19)
February	27 (8--56)	8 (4--11)
March	41 (19--75)	11 (6--15)
April	31 (15--46)	11 (11--15)
May	31 (15--46)	11 (11--15)
June	55 (34--94)	11 (8--15)
July	48 (30--75)	9 (4--11)
August	45 (25--63)	9 (8--15)
September	38 (19--64)	8 (4--14)
October	34 (8--64)	8 (4--16)
November	42 (8--83)	10 (8--14)
December	40 (8--63)	10 (8--11)

TABLE 12.

Data showing the changes in the frequency of different ray initial units in the cambial zone of Psidium guajava during 1974.

Months	Percentage				
	Uni seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi-seriate
January	40	31	21	7	1
February	43	51	6	-	-
March	38	62	-	-	-
April	38	58	3	1	-
May	43	55	2	-	-
June	42	58	-	-	-
July	44	55	1	-	-
August	63	20	17	-	-
September	58	21	21	-	-
October	34	27	33	4	2
November	52	37	10	1	-
December	56	34	9	1	-

TABLE 13.

Data showing the changes in the frequency of different ray initial units in the cambial zone of *Psidium guajava* during 1974.

Months	Percentage		
	Short	Medium	Tall
January	51	42	7
February	44	47	9
March	37	63	-
April	39	58	3
May	46	50	4
June	43	57	-
July	52	45	3
August	66	33	1
September	58	40	2
October	52	45	3
November	62	36	2
December	72	27	1

TABLE 14.

Changes in cell size of fusiform initials (as observed in tangential sections) of cambial zone in Psidium guajava during 1975. Values within parentheses indicate the range.

Months	Mean length in /u	Mean width in /u	Size of gabled end in /u
January	395 (263--430)	14 (11--23)	139 (48--219)
February	397 (262--438)	16 (11--23)	128 (56--195)
March	371 (229--560)	18 (14--27)	124 (49--211)
April	305 (225--451)	18 (14--24)	145 (74--236)
May	331 (263--470)	18 (12--23)	125 (37--195)
June	382 (262--471)	17 (14--26)	133 (70--224)
July	397 (262--525)	14 (11--19)	110 (33--261)
August	342 (228--432)	19 (12--23)	105 (23--169)
September	330 (189--432)	18 (12--21)	130 (14--224)
October	351 (280--430)	19 (11--23)	105 (34--180)
November	381 (318--486)	18 (11--24)	110 (33--210)
December	424 (336--482)	18 (14--23)	110 (53--210)

TABLE 15.

Changes in the cell size of ray initials in the cambial zone of Psidium guajava during 1975. Values within parentheses indicate the range.

Months	Ray initials	
	Periclinal diameter in /u	Anticlinal diameter in /u
January	35 (11--57)	12 (10--18)
February	27 (10--54)	10 (4-12)
March	40 (19--76)	10 (6--15)
April	31 (16--47)	11 (11--15)
May	31 (15--46)	10 (11--15)
June	65 (35--96)	11 (8--15)
July	47 (32--75)	10 (4--15)
August	45 (30--60)	9 (7--15)
September	37 (21--62)	8 (4--11)
October	34 (8--60)	8 (4--10)
November	42 (82--83)	10 (8--12)
December	40 (10--65)	10 (7--14)

TABLE 16.

Changes in the frequency of different ray initial units in the cambial zone of Psidium guajava during 1975.

Months	Percentage				
	Uni-seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi-seriate
January	40	30	20	9	1
February	41	52	7	-	-
March	38	61	1	-	-
April	38	57	4	1	-
May	44	53	3	-	-
June	42	57	1	-	-
July	45	54	1	-	-
August	63	18	19	-	-
September	57	21	22	-	-
October	36	28	30	4	2
November	52	35	12	1	-
December	57	33	8	2	-

TABLE 17.

Changes in the frequency of different ray initial units in the cambial zone of Psidium guajava during 1975.

Months	Percentage		
	Short	Medium	Tall
January	51	41	8
February	44	48	8
March	37	62	1
April	38	59	3
May	47	49	4
June	43	56	1
July	52	45	3
August	66	33	1
September	59	40	1
October	52	45	3
November	61	36	3
December	73	26	1

TABLE 18.

Changes in cell size of fusiform initials (as observed in tangential sections) of cambial zone in Psidium guajava during 1976. Values within parentheses indicate the range.

Months	Mean length in /u	Mean width in /u	Size of gabled end in /u
January	347 (262--430)	16 (11--22)	138 (49--220)
February	399 (260--440)	17 (11--23)	113 (55--195)
March	370 (229--570)	18 (14--25)	124 (56--254)
April	308 (220--451)	17 (13--24)	125 (51--211)
May	334 (263--470)	18 (14--25)	147 (75--237)
June	380 (260--469)	18 (14--26)	147 (74--237)
July	397 (260--520)	18 (14--25)	192 (75--225)
August	342 (229--430)	19 (10--24)	110 (33--265)
September	332 (190--435)	18 (11--24)	105 (23--169)
October	350 (285--430)	19 (14--25)	135 (20--260)
November	380 (317--480)	18 (13--23)	106 (34--182)
December	424 (337--482)	18 (15--23)	110 (53--211)

TABLE 19.

Changes in the cell size of ray initials in the cambial zone of Psidium guajava during 1976. Values within parentheses indicate the range.

Months	Ray initial elements	
	Periclinal diameter in /u	Anticlinal diameter in /u
January	36 (10--57)	13 (8--19)
February	27 (10--55)	7 (6--11)
March	41 (18--75)	11 (6--12)
April	30 (16--56)	11 (11--15)
May	31 (16--56)	11 (11--16)
June	56 (30--90)	11 (8--16)
July	49 (35--75)	10 (8--11)
August	45 (35--70)	9 (8--11)
September	40 (19--64)	8 (4-- 9)
October	34 (10--70)	8 (7--12)
November	42 (18--87)	10 (9--12)
December	41 (10--67)	10 (9--11)

TABLE 20.

Changes in the frequency of different ray initial units in the cambial zone of Psidium guajava during 1976.

Months	Percentage				
	Uni-seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi-seriate
January	41	31	18	9	1
February	41	50	8	1	-
March	38	61	1	-	-
April	39	56	4	1	-
May	43	55	2	-	-
June	42	57	1	-	-
July	45	53	2	-	-
August	64	20	16	-	-
September	58	22	20	-	-
October	35	27	32	4	2
November	53	37	9	1	-
December	56	35	8	1	-

TABLE 21.

Changes in the frequency of different ray initial units in the cambial zone of Psidium guajava during 1976.

Months	Percentage		
	Short	Medium	Tall
January	50	41	9
February	46	47	8
March	39	61	-
April	39	59	2
May	45	50	5
June	45	55	-
July	52	47	1
August	68	31	1
September	60	40	-
October	51	45	4
November	61	37	2
December	70	29	1

segmentation of additional fusiform cells into ray initials or by the production of new ray initials as terminal or lateral segments of the fusiform cells (Plate XXII). Occasionally, the ray initial units were seen fusing with one another, to form tall and multi-seriate compound bodies (Plates XX, XXII). This was brought about by the conversion of the intervening fusiform initial into a group of ray initials which formed the bridging connection between the two already existing groups of ray initials. Simultaneously splitting of tall ray initial units into smaller ones was also observed in this species (Plate XXII). The ray initial units of only few cells high in the beginning later grew into tall structures by the division of existing initials (Plate XXII).

Ratio of ray and fusiform initials: The different initials occurred in different proportions in different seasons of a calendar year. When their proportion was calculated on the basis of their surface area occupied in tangential sections in cambial strips, collected at fortnightly intervals, it had shown that the fusiform initials occupied 63-70% area depending on their size and ability to undergo apical intrusive growth. The ray initial varied in their proportion from 30-37% in a calendar year depending on the time of formation and proliferation (Figure 7).

STRUCTURE OF WOOD

Wood is diffuse porous in this species. The pores were of different shape and size which measured 50.55 x 40.8/u to 86.78 x 55.35/u (Table 22). They were found either solitary or in radial groups of 2-3, occasionally more. Axial parenchyma was apotracheal but diffused (parenchyma not definitely associated with vessels but scattered evenly among the fibres). They contained some ergastric substances such as tannins and starch, the intensity of which differed in the different seasons. In addition to this, there were some idioblasts which contained a single but large rhomboidal crystal of calcium oxalate in each cell. The crystals were so large that a part of them got embedded in the secondary walls of these cells (Plate XIV). The wood sclerenchyma constituted fibres and sclereids but the former predominated.

A transectional analysis of adult wood of this species had shown that the pores constituted about 20%, the axial parenchyma 3.0%, crystalliferous idioblast 2% and sclerenchyma 50.0% (Figure 8) of the total transectional area of wood. A similar estimation of the different components of the axial system, in round the year collection for three consecutive years, has revealed that they differed to certain extent in the different seasons. The vessel area varied from 20-24% in a year (Figure 9). Similarly, the amount of other components

TABLE 22.

Seasonal variations in the dimension of vessel elements of Psidium guajava. Figures within parentheses indicate the range.

Months	Dimension of vessel elements in μ	
	Anticlinal diameter	Periclinal diameter
January	54.45 (15.00--82.50)	48.45 (15.00--90.00)
February	57.3 (33.75--75.00)	49.2 (33.75--63.75)
March	50.55 (26.25--78.75)	40.80 (26.25--56.25)
April	86.78 (18.75--88.75)	55.35 (33.75--78.75)
May	52.8 (33.75--56.25)	44.75 (37.70--63.75)
June	54.25 (26.25--67.50)	54.9 (33.75--75.00)
July	60.75 (37.50--82.50)	45.05 (41.25--67.50)
August	59.00 (41.25--78.75)	54.15 (41.25--63.75)
September	54.90 (37.50--78.75)	46.95 (33.75--63.75)
October	63.05 (41.25--86.25)	55.2 (41.25--78.75)
November	45.05 (26.25--90.00)	47.25 (30.00--63.75)
December	62.55 (30.00--78.75)	44.05 (26.25--56.25)

also differed in the different seasons. The axial parenchyma varied from 1-6% (Figure 10), the crystalliferous from 1-6% (Figure 11) and the sclerenchyma 42-51% (Figure 12).

The wood was traversed by horizontally running ray system which appeared quite distinct in transection as black streaks when observed through hand lense. This system in transectional view constituted about 25% area in the adult wood (Figure 8). This also varied from 20-30% in different seasons (Figure 13), the maximum being in April.

The rays were of heterogenous type in the wood. They were composed of two morphological types, procumbent and upright elements. Their nature became quite distinct in radial longitudinal sections (Plate XIV). Further, the population of ray cells in a fusiform ray unit as viewed in tangential sections appeared quite heterogenous. Even among the procumbent elements some of them were vertically elongated and others were small and almost isodiametric. In other words, the ray cells were of uneven size and shape, even in the same ray unit (Plate XIV).

The wood rays, as their mother initial in the cambium, differed in height and width to a considerable extent. They varied in height from 1-40 cells and in width from 1-5 cells. Microscopic examination of the immediate xylem derivative in fortnightly collections for three consecutive years had shown that the tall rays were more frequent in October and November

while the short ones in the rest of the months (Table 23). The broad rays were more in January and October and the uniseriate in April, August and September months (Table 24). All the ray types together constituted 32.83% of the total area of xylem of the adult wood when viewed in tangential sections. The estimation of area occupied by these ray parenchyma cells in the different seasons had shown that it varied from 28-36% (Figure 14).

Specific test for the starch content of the axial parenchyma was made to note the fluctuation of starch intensity. It was found that in certain months of the year, these parenchyma cells had stored more starch than in others while the starch contents became almost exhausted in June, July, August and November. Similar observations on ray cells also had shown that the amount of starch varied in different months of a calendar year. The ray cells became rich in starch in the month of February and September and poor in April and July (Plate XVIII). No trace of starch was noticed in October and November. The starch content in the axial and horizontal systems did not show any relationship. When the axial system was rich, the ray system showed either poor or only a moderate amount of starch. In June, July and August the axial system did not give any positive result for starch test while the ray system had shown the positive indication of starch, although its presence in low quantity (Table 25).

Similar observations on tanniferous contents in the two systems of wood parenchyma had shown that the ray cells

TABLE 23.

Changes in the frequency of ray units in the xylem of Psidium guajava during 1974.

Months	Percentage		
	Short	Medium	Tall
January	55	43	2
February	50	48	2
March	49	51	-
April	45	53	2
May	44	53	3
June	44	56	-
July	60	38	2
August	58	40	2
September	58	42	-
October	50	46	4
November	60	35	5
December	70	29	1

TABLE 24.

Changes in the frequency of different ray units in the xylem of *Psidium guajava* in different months.

Months	Percentage				
	Uni-seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi-seriate
January	43	30	21	6	-
February	40	49	10	1	-
March	47	50	3	-	-
April	54	39	5	2	-
May	41	55	4	-	-
June	40	58	2	-	-
July	41	58	1	-	-
August	60	25	15	-	-
September	55	23	20	2	-
October	30	28	34	6	2
November	50	34	13	2	1
December	52	32	14	2	-

TABLE 25.

Seasonal variations in the amount of starch and tannins in the axial and ray parenchyma cellsof xylem in Psidium guajava.

Months	TANNINS		STARCH	
	Axial parenchyma	Ray paranchyma	Axial parenchyma	Ray paranchyma
January	-	+	++	+
February	-	+	+++	++
March	-	+	+++	+
April	-	+	++	+
May	-	++	++	+
June	-	+++	-	+
July	-	++	-	+
August	+	+	-	+
September	+	+	+	++
October	-	++	+	-
November	-	++	-	-
December	-	+	+++	+

\- = Absent
\+ = Poor
++ = Moderate
+++ = Rich.

contained tanniferous substances in all the months, but to a varying degree. The heaviest depositions of tannin was observed in June, moderate in May, July, October and November and poor in the rest months. The axial parenchyma had shown the presence of tannins only in August and September. They were observed rarely in February and were totally absent in rest of the months (Table 25).

The immediate derivatives of cambium towards xylem side were analysed every month in order to find out the variations in the size of vessel elements and xylem fibres, produced in different seasons.

The macerated narrow vessel elements, whose diameter ranged from 11-35/u (Type - I) were found less frequently from April to June than in other months and at the same time the medium size (Type - II) and broad ones (Type - III) were comparatively abundant during this period (Table 26). As regards the length of vessel elements, it was found that vessels varied in length from 75-637.5/u and from 15-101/u in width. It is evident from the table 27 that the longer elements were found in October, November, December and January and short in the other months. They mostly bore a single wide pore at their terminal end walls - simple perforation plates, and crowded simple pits on lateral walls which communicate with the contiguous elements through pit membrane. Most of the vessels exhibited tails of different size on one or both the ends. These tails appeared to have been produced due to intrusive growth. In certain cases the size of the tails went upto 112/u (Plate XIV).

TABLE 26.

Data on the number and percentage of vessel types in Psidium guajava. Figures within parentheses indicate the range.

Months	Type- I (Small) (11--35/u)		Type- II(Medium) (36--60/u)		Type- III(Large) (61--100/u)	
	Average No. of pores per field	% of pores	Average No. of pores per field	% of pores	Average No. of pores per field	% of pores
January	2 (1--4)	36.20	3 (2--6)	40.00	4 (2--7)	23.80
February	5 (1--12)	30.20	6 (4--8)	39.80	5 (3--8)	30.00
March	2 (1--4)	29.10	6 (4--11)	38.06	4 (3--6)	32.84
April	2 (1--5)	17.71	4 (2--6)	44.00	3 (1--5)	38.29
May	2 (1--4)	20.81	4 (2--6)	46.82	3 (1--4)	32.37
June	2 (1--5)	23.12	5 (3--7)	53.23	2 (1--6)	23.65
July	4 (1--10)	30.07	7 (3--9)	46.15	3 (1--5)	23.78
August	4 (1--8)	28.11	6 (2--10)	46.59	3 (1--7)	25.30
September	4 (1--7)	36.29	6 (2--12)	40.94	2 (1--6)	22.77
October	4 (1--6)	32.12	6 (2--11)	44.78	2 (1--12)	23.10
November	4 (2--7)	33.60	5 (2--8)	42.16	3 (1--5)	24.24
December	2 (1--5)	27.74	4 (2--6)	46.82	2 (1--5)	25.44

TABLE 27.

Seasonal variation of vessel size in Psidium guajava.

Months	Length of vessel elements in μ		
	Minimum	Maximum	Average
January	206.25	637.50	414.15
February	168.75	450.00	338.55
March	150.00	412.50	361.05
April	112.50	431.25	332.95
May	187.50	431.25	320.85
June	150.00	450.00	350.15
July	112.50	412.50	319.85
August	150.00	431.25	299.00
September	75.00	457.50	302.23
October	225.00	573.75	414.25
November	232.50	461.25	399.81
December	168.75	543.75	410.25

The macerated fibre elements appeared as elongated structures with tapering ends, enclosing a narrow or obliterated lumen in the centre. They appeared to undergo apical elongation by means of intrusive growth. This became evident when their apical structures had been examined. The intrusively grown elements exhibited newly formed apical parts made up of comparatively thin cellulose walls enclosing bigger lumen, rich in cytoplasmic contents. Such apices often exhibited various types of structural manifestations, such as serrations, forkings, bending etc. They varied in length from 390-999/u with an average length, varying from 520-720/u and in width from 6-24/u with an average varying from 12-17/u (Table 28). A comparison of their average size with the average size of fusiform initials had shown that the fibre elements had grown 1.4/3.33 times more than the fusiform initials.

TABLE 23.

Seasonal changes in the dimension of xylem fibres of Psidium guajava. Figures within parentheses indicate the range.

Months	Length of fibres in /u	Width of fibres in /u
January	520 (390--850)	15 (6--22)
February	690 (422--990)	15 (11--22)
March	665 (402--900)	13 (6--15)
April	650 (412--650)	14 (6--22)
May	692 (425--990)	12 (10--20)
June	720 (395--989)	16 (6--24)
July	590 (450--989)	17 (6-23)
August	605 (410--978)	15 (11--19)
September	610 (402--925)	14 (6--24)
October	710 (409--999)	17 (11--24)
November	670 (399--980)	15 (6--22)
December	595 (427--855)	17 (11--23)

STUDIES ON BARK

The term bark is used in the present study to include all tissues lying outside vascular cambium of the axis, in an either primary or secondary state of growth. In the young shoots and roots the bark constituted the different phloem components, the pericycle, endodermis, the cortex and the epidermis, while in the older regions the secondary phloem and the periderm formed the bark. Externally, the bark of guava appeared as smooth and grey (Plate II). Internally it was made up of three structural zones viz., the conducting, non-conducting and periderm.

The conducting phloem was composed of sieve elements accompanied with companion cells, the axial parenchyma and the ray parenchyma (Plate XVII). Occasionally, sclereids also formed part of this region. The non-conducting phloem formed the major part of the adult bark and constituted mainly the parenchyma cells (Plate XVII). Sclereids in this region took a prominent appearance as they generally assumed larger proportions, arranged in tangential bands wherever they occurred (Plate XV). This region was prominently marked by the absence of sieve elements and the associated companion cells, and the dilatated rays (Plate XVII). The periderm which formed the third and the outermost zone was represented

by a thin strip of phellem, a single layer of phellogen and a few layers of phelloderm (Plate IX).

The axial and ray parenchyma contained varying amounts of ergastric substances such as tannin, starch and calcium oxalate crystals of different shape and size (Plate XIX), depending on the season.

A transectional analysis of the conducting phloem of this species had shown that the sieve elements constituted in average about 35%, the axial parenchyma 36% and the ray parenchyma 30% of the total transectional area. However, the estimation of the different components of conducting phloem in round the year collection for three consecutive years had revealed that they differed to certain extent in the different seasons. The sieve-tube area varied from 34-43% (Figure 15), the axial parenchyma from 24-41% (Figure 16) and the ray parenchyma from 25-35% (Figure 17).

Similar analysis of the non-conducting phloem round the year basis had revealed that percentage area occupied by ray parenchyma varied from 32-49% (Figure 18), with an average of 38%, which was about 8% higher from the value obtained in case of conducting phloem. The obvious reason for the increase of ray parenchyma in non-conducting zone of phloem is due to the widening of rays towards the periphery and the simultaneous obliteration of the sieve elements.

Estimation of the ray component in tangential plane in round the year collections had revealed that the average

area occupied by the ray parenchyma in conducting phloem varied from 26-32% (Figure 19), with an average of about 30% which was almost equal to the transectional value, described earlier. Similarly, the area occupied by ray parenchyma of the non-conducting phloem varied from 31-58% (Figure 20) in different seasons with an average of 40% which was 2% more than what was obtained in transectional values.

The phloem rays, as their mother initials in the cambium, differed in height and width to a considerable extent. They varied in height from 1-38 cells. Microscopic examination of the immediate phloem derivatives in fortnightly collections for three consecutive years had shown that the tall rays were more frequent in March, October and November while the short ones in May, June, July, August, September and October (Table 29), the broad ones in January, February, September, October and November and uniseriate in March, April, May, June and July (Table 30).

A similar study of the non-conducting zone of phloem had shown that the tall rays were more frequent in January, August, September and October, while short ones in February, March, April, August, September and October (Table 31), the broad ones in February, April, August, September and October, and the uniseriate in May, June, July, August, September and December (Table 32). All the ray types together constituted in average 30% area in conducting and about 40% area in non-conducting phloem respectively.

TABLE 29.

Changes in the frequency of ray unit types in the conducting phloem of Psidium guajava.

Months	Percentage		
	Short	Medium	Tall
January	46.2	52.1	1.7
February	52.2	46.8	1.0
March	56.8	40.4	2.8
April	50.1	49.9	-
May	59.6	40.4	-
June	88.5	11.5	-
July	80.3	19.7	-
August	78.2	21.8	-
September	76.1	22.9	1.0
October	63.5	34.0	2.5
November	55.5	41.5	3.0
December	51.2	47.8	1.0

TABLE 30.

Changes in the frequency of different ray unit types in the conducting phloem of Psidium guajava.

Months	Percentage				
	Uni-seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi-seriate
January	29.8	34.5	32.0	3.7	-
February	31.2	33.6	32.2	3.0	-
March	47.9	41.1	9.8	1.2	-
April	48.5	40.5	8.8	2.2	-
May	39.5	48.5	11.0	1.0	-
June	38.8	49.8	11.4	-	-
July	40.2	50.8	9.0	-	-
August	30.5	48.4	19.2	1.9	-
September	29.6	49.7	17.6	3.1	-
October	29.0	49.3	18.1	3.6	-
November	30.2	35.7	31.0	3.1	-
December	28.8	36.2	33.0	2.0	-

TABLE 31.

Changes in the frequency of different ray unit types in the non-conducting phloem of Psidium guajava.

Months	Percentage		
	Short	Medium	Tall
January	64.2	34.1	1.7
February	80.5	19.5	-
March	83.6	15.2	1.2
April	81.5	17.1	1.4
May	75.3	24.7	-
June	70.1	29.9	-
July	72.2	26.8	1.0
August	80.0	18.0	2.0
September	82.3	15.7	2.0
October	81.5	16.1	2.4
November	75.6	24.4	-
December	70.5	28.3	1.2

TABLE 32.

Changes in the frequency of different ray unit types in the non-conducting phloem of Psidium guajava.

Months	Percentage				
	Uni-seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi-seriate
January	29.0	56.8	14.2	-	-
February	30.2	52.8	11.0	6.0	-
March	29.1	47.9	23.0	-	-
April	23.8	58.2	10.8	2.2	-
May	40.2	49.8	10.0	-	-
June	39.1	39.1	21.8	-	-
July	46.2	42.8	10.0	1.0	-
August	35.5	37.5	22.0	5.0	-
September	32.2	33.9	22.6	11.3	-
October	30.5	35.5	25.2	8.8	-
November	29.8	55.2	15.0	-	-
December	31.9	54.1	13.5	0.5	-

Specific test for the starch content of axial and ray parenchyma was made to note the fluctuation of the starch intensity. It was found that in certain months of the year axial parenchyma cells had stored more starch than in the others and in certain other months the starch contents became almost exhausted e.g., August. Similar observations on the ray cells had shown that the amount of starch varied in different months of a calendar year. The ray cells became rich of starch in January and February, poor in July, November and December (Plate XVIII) and completely devoid of starch in August. A study of the non-conducting phloem had revealed the presence of some starch in the axial as well as in the ray parenchyma and no starch in November (Table 33).

The starch content in the axial and horizontal systems exhibited a close relationship both in the conducting and in non-conducting phloem.

Similar observations on tanniferous contents in both, the ray as well as axial parenchyma had shown that the ray cells contained tanniferous substances in all the months but their intensity varied with the season. The heaviest deposition of tannin was observed in May and June, poor in February, August and September and moderate in the rest of the months. The axial parenchyma were rich in tannins in January, May and June, moderate in March, July, October and December and poor in the rest of the months. In axial parenchyma of non-conducting phloem, the heaviest deposits of tannins were noted in January, March, May and December, moderate in June,

TABLE 33.

Seasonal variation in the amount of starch in the bark of *Psidium guajava*.

Months	Conducting phloem		Non-conducting phloem	
	Axial parenchyma	Ray parenchyma	Axial parenchyma	Ray parenchyma
January	+++	+++	+++	+++
February	+++	+++	+++	+++
March	+	+	+	+
April	+	+	+	++
May	+	+	+	++
June	+	+	+	++
July	+	+	+	++
August	-	-	-	-
September	+	+	+	++
October	+	+	+	++
November	-	+	+	+
December	+	+	+	+

\- = Absent
\+ = Poor
++ = Moderate
+++ = Rich

July, October and November and poor in February, April, August and September (Table 34).

The inner phloem adjacent to cambium was analysed every month in order to find out the variations in the size of sieve-tube members, produced in different seasons. The sieve-tube members varied in length from 87-615/u and from 7.5 x 7.5 to 26.25 x 30.00/u in width. It is evident from the table 35 that the longer elements were found in February and November and comparatively short ones in the other months. But no significant change was noted in the lumen size of the sieve elements in different seasons (Table 36). The sieve-tube members bore a number of specialized sieve areas arranged in scalariform manner at their oblique terminal walls constituted the compound sieve plates (Plate XVI). Lateral walls also possessed over-crowded sieve areas which communicated with the contiguous laterally placed elements through sieve pores (Plate XVI). The sieve-tube members were disposed end to end in long series (Plate XVI). The sieve pores found on the lateral walls were smaller than the pores of sieve plates. Each sieve-tube member consisted of one or more closely associated companion cells which measured almost equal in length with the sieve tube member (Plate XVI). A few sieve-tube members were found possessing tails which appeared to have been produced due to intrusive growth. In certain cases the size of the tails went upto 45/u in length.

TABLE 34.

Seasonal variation in the amount of tannins in the bark of *Psidium guajava*.

Months	Conducting phloem		Non-conducting phloem	
	Axial parenchyma	Ray parenchyma	Axial parenchyma	Ray parenchyma
January	+++	++	+++	++
February	+	+	+	+
March	++	++	+++	++
April	+	++	+	++
May	+++	+++	+++	+++
June	+++	+++	+++	+++
July	++	++	++	++
August	+	+	+	+
September	+	+	+	+
October	++	++	++	++
November	+	++	++	++
December	++	++	+++	++

\- = Absent
\+ = Poor
++ = Moderate
+++ = Rich.

TABLE 35.

Seasonal changes in cell size of sieve-tube elements of *Psidium guajava*.

Months	Length of sieve-tube members in /u		
	Minimum	Maximum	Average
January	160.00	356.25	251.25
February	95.00	580.10	417.75
March	187.50	450.56	314.25
April	112.50	318.75	249.75
May	131.25	293.75	284.45
June	87.00	318.75	251.60
July	225.10	376.50	313.20
August	187.50	318.75	248.25
September	187.50	375.50	313.20
October	180.10	337.50	271.76
November	262.50	615.00	378.00
December	131.25	299.25	289.90

TABLE 36.

Width variation of sieve-tube elements in Psidium guajava. Figures within parentheses indicate the range.

Months	Width of sieve-tube elements in μ	
	ANTICLINAL DIAMETER	PERICLINAL DIAMETER
January	15.75 (11.25--22.5)	17.25 (11.25--22.25)
February	15.38 (11.25--22.5)	19.88 (15.0 --22.5)
March	18.00 (15.0 --22.5)	20.25 (15.0 --26.25)
April	19.13 (15.0 --26.25)	22.5 (15.0 --26.25)
May	13.86 (11.25--18.75)	18.00 (15.0 --22.50)
June	14.25 (7.50--22.50)	17.25 (11.25--26.25)
July	18.00 (11.25--26.25)	16.13 (11.25--22.50)
August	15.38 (11.25--18.75)	21.75 (15.0 --26.25)
September	15.00 (7.50--18.75)	24.75 (18.75--30.00)
October	16.13 (15--22.50)	22.13 (15.00--26.25)
November	13.86 (7.5 --18.75)	21.00 (18.75--22.50)
December	13.13 (7.5---18.60)	16.13 (7.5---22.50)

The walls of sieve elements were cellulosic, distinct nacreous thickenings developed on the primary walls. The sieve element protoplast lacked nucleus at maturity. The companion cells and sieve-tube members exhibited a close ontogenetic relation as they developed from the same mother cells. The modified primary pit fields found on the walls of sieve-tubes called as sieve pores were found to have a coat of callose on the inner phase. The amount of callose fluctuated with the change of weather. Sometimes they were found forming a pad-like structure over the sieve plates, the callose pads (Plate XVII).

DEVELOPMENTAL CHANGES IN CAMBIUM

In the growing shoots the vascular cambium began its development at the basal internode and proceeded acropetally towards the apex. The differentiation of cambial initials out of procambial cells was quick and very soon it became a complete ring. The changes in the cambial structure regarding the size of its different components and their relative proportaion was studied in branches of varying age and size. It was found that the cambial initials, especially the fusiform ones, had undergone considerable size variation with the growing girth of the axis. They were shorter in younger axis than the older ones. With the increase in the circumference of the cambial cylinder there was a corresponding increase in the length of fusiform initials till they reached their maximum size (396/u). It was followed by a slight decline in length of the initials which remained more or less constant upto the base (Table 37). This increase in the size of fusiform initials went upto 38.50% over its original size found in the current year shoot. A similar observation on the ray initials showed that they did not undergo any significant change in their individual dimension (Table 38) but they underwent greater multiplication resulting in the greater volume of the ray initial units. In older axis and in the trunk of the older trees ray initials were invariably multiseriate and tall than

TABLE 37.

Changes in the cell size of the fusiform initials (as observed in tangential sections) in the cambial zone of Psidium guajava with the growing circumference of the axis. Values within parentheses indicate the range.

Circumference of the axis in cm	Mean length in /u	Mean width in /u	Size of gabled ends in /u
1	286 (165--401)	11 (9--22)	112 (49--236)
2	302 (200--543)	12 (9--22)	120 (58--312)
10	310 (223--427)	12 (9--22)	127 (45--209)
30	372 (223-427)	18 (13--27)	128 (58--258)
72	392 (267--543)	18 (13--27)	152 (45--267)
92	396 (312--489)	18 (13--27)	149 (71--231)
108	390 (312--490)	16 (13--22)	147 (53--245)
140	385 (280--579)	22 (18--24)	170 (53--296)
184	384 (320--578)	17 (13--22)	190 (89--311)
192	384 (298--445)	19 (13--22)	192 (44-312)

TABLE 38.

Changes in the cell size of ray initials (as observed in tangential sections) in the cambial zone of Psidium guajava with the growing circumference of the axis. Values within parentheses indicate the range.

Circumference of the axis in cm.	Ray initial	
	Periclinal diameter in /u	Anticlinal diameter in /u
1	23 (9--67)	9 (5--13)
2	21 (5--80)	12 (5--18)
10	22 (9--76)	12 (5--18)
30	22 (9--67)	13 (9--22)
72	21 (9--80)	17 (9--53)
92	24 (5--67)	11 (5--18)
108	24 (9--53)	13 (5--27)
140	24 (9--98)	11 (5--18)
184	25 (5--49)	13 (5--22)
192	21 (9--53)	13 (5--18)

in the younger shoots (Plate XX). As a consequence, the ray initials occupied greater area in the cambial cylinder of the older parts of the tree as compared to younger ones. The tall and broad rays were more frequent in the trunks than in the young shoots (Tables 39, 40).

With the growth of the axis the cambial cylinder also expanded by adding more cells. The fusiform initials underwent pseudotransverse divisions and gave rise to sister initials, some of which repeated the process, others fed away and still others subsequently gave rise to ray initials. Similarly some ray initials were ultimately lost from the cambium, others divided and gave rise to new ray initials. All these happened in order to cope up with the expansion of the axis.

Vascular cambium, therefore, constantly underwent changes in its composition and dimension as an accommodative measure to meet the increasing circumference of vascular cylinder. This usually resulted in a considerable change in the corresponding volume of the different initials. In the young axis the fusiform initials occupied about 80% of the total area of the cambium cylinder while in mature trunks they were reduced in number and occupied only about 63% of the total area. Once this condition was attained, a relatively constant ratio was maintained between the ray and fusiform initials (Figure 21).

TABLE 39.

Changes in the frequency of different ray initial units in the cambial zone of Psidium guajava with the growing circumference of the axis.

Circumference of the axis in cm.	Percentage		
	Short	Medium	Tall
1	96	4	-
2	96	4	-
10	88	12	-
30	80	18	2
72	77	19	4
92	84	15	1
108	70	26	4
140	84	14	2
184	81	17	2
192	84	15	1

TABLE 40.

Changes in the frequency of different ray initial units in the cambial zone of Psidium guajava with the growing circumference of the axis.

Circumference of the axis in cm	Percentage				
	Uni-seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi-seriate
1	99	1	-	-	-
2	84	15	1	-	-
10	67	24	9	-	-
30	63	17	20	-	-
72	60	15	25	-	-
92	62	23	15	-	-
108	61	10	26	3	-
140	65	17	17	1	-
184	63	21	16	-	-
192	63	16	19	1	1

DEVELOPMENTAL CHANGES IN SECONDARY XYLEM

The amount of wood increased with the increase in the age of the axis. The rate of increment of wood as compared to that of bark was found to be manifold (Figure 22). With the increase in the age of the mother meristem (vascular cambium) described earlier, the amount and structure of wood also appeared to undergo considerable changes.

The structural changes of wood were studied in the axes of different girths, collected from the same tree at different height levels. The different elements including the lumen size of the vessel pores varied in size with the axis girth. Both, the radial diameter as well as the tangential one, showed an increase with the increasing diameter of the axis. This increase was gradual from younger to older shoots until a maximum was reached. Following this no change in size was noticed with the further increase in size of the trunk. The radial diameter remained always larger than the tangential one (Table 41).

On the basis of the pore size the vessels were classified into three types viz., small (11-35/u), medium(36-60/u)and large(61-100/u). A survey of the above categories of vessels was made in the axes of different diameters. In shoots of lesser diameter, the small type vessels were found to be

TABLE 41.

Changes in the vessel diameter of Psidium guajava with the growing circumference of the axis. Figures within parentheses indicate the range.

Circumference of the axis in cm.	Diamension of vessel elements in /u	
	Radial diameter	Tangential diameter
1	37.5 (22.25--62.30)	27.23 (13.35--48.95)
2	66.75 (26.70--115.70)	49.4 (22.25--89.00)
10	67.73 (26.70--106.80)	53.38 (35.60--75.65)
30	69.30 (44.50--108.00)	61.50 (35.60--89.00)
72	82.86 (22.25--111.25)	68.88 (31.15--97.90)
92	86.41 (48.95--129.05)	71.64 (35.60--74.50)
108	87 (31.15--112.25)	68.86 (31.15--80.10)
140	94.04 (31.15--120.15)	69.86 (48.95--89.00)
184	94.12 (66.75--120.15)	70.85 (44.50--89.00)
192	92.12 (44.50--129.05)	73 (40.05--115.70)

90-100% while in the older axes and in the main trunk their percentage fell to the minimum (33%). With the decrease in number of small type vessels a gradual increase in the medium and large type vessels appeared with increase in the girth of the axis (Figure 23). Further, the number of pores per field also showed a sharp decline from young to old axes (Table 42).

In the younger axis no characteristic distribution of vessels was noticed, as the number of vessels was numerous, they were distributed at random without any particular pattern. On the other hand, in adult trunks the vessels tended to form groups mostly of 2-3, arranged in radial rows.

The length of vessel members like their width showed a corresponding increase with the increase in the stem diameter. That is to say the short vessels were more frequent in young shoots than in older ones. The average size of vessels found in the current years' shoot measured about 284/u while the average of vessels isolated from adult trunk came about 404/u (Table 43).

A transectional analysis regarding the percentage area occupied by the different components of xylem in the wood samples collected from the axis of varying diameter revealed that they differed to certain extent in the different samples. The vessel area varied from 19-24% (Figure 24), the minimum being in the youngest shoot. Similarly the amount of other components also differed in different samples. The axial

TABLE 42.

Changes in the number and percentage of different types of vessels in the xylem of Psidium guajava with the increasing circumference of the axis. Figures within parentheses indicate the range.

Circumference of the axis in cm.	Type- I (Small) (11--35/u)		Type-II (Medium) (36--60/u)		Type-III (Large) (61--100/u)	
	Average No. of pores per field	% of pores	Average No. of pores per field	% of pores	Average No. of pores per field	% of pores
1	79 (60--105)	100	-	-	-	-
2	18 (13--23)	90	2 (2--3)	10	-	-
10	12 (5--23)	60	7 (2--12)	35	1 (1--5)	5
30	4 (2---9)	50	3 (1---8)	37.5	1 (1--3)	12.5
72	4 (2---8)	55.6	3 (1---7)	33.3	2 (1--4)	11.1
92	5 (3---7)	50	4 (3---5)	40	1 (1--3)	10
108	4 (2---6)	55.6	3 (2---6)	33.3	2 (1--4)	11.1
140	5 (3---6)	33.33	6 (3--10)	39.09	4 (3--5)	27.58
184	4 (3---7)	34.36	4 (3---8)	38.36	3 (3--5)	27.28
192	6 (1---8)	46.16	4 (3---6)	30.8	3 (1--4)	23.04

TABLE 43.

Changes in the vessel length of Psidium guajava with the increasing circumference of the axis.

Circumference of the axis in cm.	Length of vessel element in μ		
	Minimum	Maximum	Average
1	89	401	284
2	188	445	310
10	134	421	313
30	189	423	330
72	267	490	340
92	178	578	351
108	134	623	349
140	133	578	390
184	267	534	404
192	188	530	398

parenchyma varied from 1-4% (Figure 25), the crystalliferous from 0-4% (Figure 26), the xylem ray parenchyma from 14-25% (Figure 27), and the sclerenchyma from 45-66% (Figure 28). In tangential longitudinal sections, the percentage area occupied by ray parenchyma and crystalliferous parenchyma varied from 20-39% and 0-8% respectively and in both the cases the average values were found slightly higher than the transectional values.

The wood rays, as their mother initials in the cambium, differed in height and width to a considerable extent, with the age of the axis. They vary in height from 1-39 cells and in width from 1-5 cells. In older axis and in the trunk of older trees ray units were invariably multiseriate and tall than in the younger shoots. As a consequence, the ray units occupy greater area in xylem of the older trees as compared to younger ones. The tall and broad rays occurred more frequently in the trunks than in the younger shoots (Tables 44, 45). All the ray types together constituted 20-39% area in the axes of different thickness, the maximum being in the thickest.

The xylem fibres also exhibited a clear difference in length with regard to the increasing circumference of the axis. However, the length and width average ranged from 428-660/u and 11-23/u respectively. The minimum length of the fibre was found to be 310/u and the maximum upto 1125/u, the minimum and maximum width were noted 6/u and 23/u respectively (Table 46).

TABLE 44.

Changes in the frequency of ray unit types in the xylem of *Psidium guajava* with the increasing circumference of the axis.

Circumference of the axis in cm.	Percentage		
	Short	Medium	Tall
1	61.8	38.2	-
2	54.2	45.8	-
10	47.6	49.4	3
30	55.0	40.0	5
72	52.0	48.0	-
92	49.0	46.0	5
108	45.0	48.0	7
140	57.0	42.0	1
184	54.0	46.0	-
192	50.0	47.0	3

TABLE 46.

Changes in the frequency of ray units in the xylem of *Psidium guajava* with the increasing circumference of the axis.

Circumference of the axis in cm.	Percentage				
	Uni-seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi seriate
1	98	2	-	-	-
2	75	25	-	-	-
10	39	48	13	-	-
30	50	23	24	3	-
72	53	25	22	-	-
92	45	35	20	-	-
108	43	32	24	1	-
140	45	32	23	-	-
184	48	31	18	2	1
192	45	29	25	1	-

TABLE 46.

Changes in the dimension of xylem fibres of Psidium guajava with the increasing circumference of the axis. Figures within parentheses indicate the rate.

Circumference of the axis in cm.	Xylem fibres	
	Length in μ	Width in μ
1	540 (310--750)	17 (11--23)
2	428 (380--750)	14 (11--19)
10	469 (380--775)	14 (11--19)
30	528 (390--863)	14 (11--15)
72	509 (412--837)	12 (6--19)
92	607 (431--900)	23 (6--24)
108	660 (420-1125)	15 (6--23)
140	604 (430--975)	11 (6--15)
184	590 (450--925)	17 (6-23)
192	597 (425--985)	16 (11--23)

DEVELOPMENTAL CHANGES IN THE SECONDARY PHLOEM

The amount of phloem increased with the increase in the age of axis. The rate of increment of the phloem as compared to that of wood was found much less (Figure 22). With the increase in the age of mother meristem (vascular cambium) the amount and structure of phloem also appeared to undergo some changes.

The structural changes of the phloem were studied in the axis of different girth from the same tree at different height levels. The different elements including the lumen size of sieve-tube members, varied with the girth of the axis. Both the radial diameter as well as the tangential one showed an increase with the increasing diameter of the axis. This increase was gradual from younger to older shoots until the maximum was reached. Following this, no significant change in size was noticed with the further increase in size of the trunk. The tangential diameter was found always higher than the radial one irrespective of the girth of the axis (Table 47).

The length of sieve-tube members, like their width, showed a corresponding increase with the increase in the stem diameter. Thus, the short sieve elements were more frequent in young shoots than in the older ones. The average size of

TABLE 47.

Changes in the sieve-tube diameter of Psidium guajava with the growing circumference of the axis. Figures within parentheses indicate the range.

Circumference of the axis in cm.	Sieve-tube elements	
	Radial diameter in μ	Tangential diameter in μ
1	9.38 (7.50--15.00)	12.00 (9.25--15.00)
2	9.37 (7.50--15.12)	13.25 (7.63--16.50)
10	9.38 (7.50--11.25)	14.25 (7.53--15.50)
30	9.75 (7.50--11.25)	15.38 (15.00--18.75)
72	15.38 (7.50--22.50)	19.88 (15.00--22.50)
92	18.00 (15.13--22.50)	21.00 (18.75--22.50)
108	19.63 (7.50--20.75)	22.88 (7.5--26.25)
140	17.13 (7.50--22.50)	20.63 (11.25--25.75)
184	18.00 (7.5--19.50)	20.13 (11.25--21.75)
192	18.25 (7.5--22.5)	21.00 (15.00--26.25)

sieve-tube members found in the current year shoot measured about 205/u while the average of sieve elements isolated from adult trunk was found upto 358/u (Table 48).

Some of the sieve-tube members showed indication to have grown intrusively. Such elements had tails of varying size but they did not show any forking or serration as fibres of xylem. The intrusively grown elements measured longer than the cambial cell from which they had developed, while others were either short or almost equal in size.

Intrusive growth in sieve-tube members was observed in all the positions in relation to cambium but only to a limited extent. The percentage of sieve-tube members showing sign of intrusive growth was found to be 5.3% in average. In general bipolar growth appeared to be more prevalent than the monopolar type (Table 49).

The phloem ray, like their mother initials in the cambium differed in height and width to a considerable extent with the age of the axis in conducting as well as in non-conducting phloem. They varied in height from 1-37 cells and in width from 1-4 cells. In the bark of older trees ray units were invariably tall and broad than in the younger shoots (Tables 50, 51). As a consequence the ray units occupied greater area in the bark of older trees as compared to younger ones. All the ray types together constituted 16-40% area in the axes of different thickness with an average of about 29%.

TABLE 48.

Changes in the sieve-tube length of Psidium guajava with the growing circumference of the axis.

Circumference of the axis in cm.	Length of sieve-tube elements in /u		
	Minimum	Maximum	Average
1	134	334	205
2	178	445	257
10	200	587	303
30	223	446	320
72	125	579	358
92	125	472	350
108	137	467	322
140	89	454	320
184	223	445	310
192	223	623	319

TABLE 49.

Percentage of sieve-tube members showing intrusive growth.

Distance from cambium in /u	Mono-polar	Bi-polar	Total
100	2.0	3.2	5.2
200	1.8	3.2	5.0
400	2.7	2.4	5.1
600	1.6	3.2	4.8
800	1.6	3.0	4.6
1000	2.8	2.3	5.1
1200	2.0	3.0	5.0
1400	3.0	2.4	5.4

TABLE 50.

Changes in the frequency of ray units in the conducting phloem of Psidium guajava with the increasing circumference of the axis.

Circumference of the axis in cm.	Percentage		
	Short	Medium	Tall
1	76.7	23.3	0.0
2	88.7	11.3	0.0
10	81.2	18.8	0.0
30	79.1	20.0	0.9
72	81.9	18.1	0.0
92	76.1	21.9	2.0
108	63.5	34.5	2.0
140	62.5	36.2	1.3
184	55.5	44.5	0.0
192	53.2	45.8	1.0

TABLE 51.

Changes in the frequency of different ray units of *Psidium guajava* with the increasing circumference of the axis.

Circumference of the axis in cm.	Percentage				
	Uni-seriate	Bi-seriate	Tri-seriate	Tetra-seriate	Multi-seriate
1	95.8	4.2	-	-	-
2	95.9	4.1	-	-	-
10	60.9	35.1	4.0	-	-
30	34.6	43.6	21.8	-	-
72	49.0	37.1	13.9	-	-
92	48.5	38.5	13.0	-	-
108	39.5	40.6	18.9	1.0	-
140	40.9	40.1	16.8	2.2	-
184	39.8	42.2	17.0	1.0	-
192	38.2	39.8	20.0	2.0	-

A transectional analysis regarding the percentage area occupied by the different components of phloem samples collected from the axis of varying diameter has revealed that they differed to a certain extent in different samples. The sieve-tube area varied from 30-37% (Figure 29), the maximum being in the old shoot. Similarly, the amount of other components also differed in different samples. The axial parenchyma varied from 33-53% (Figure 30) and the ray parenchyma from 17-30% (Figure 31).

In tangential longitudinal sections the percentage area occupied by ray parenchyma in the conducting phloem varied from 16-40% (Figure 32) which is slightly higher than the transectional value. Unlike the sieve-tube members, the amount of ray parenchyma showed an increasing trend with the increase in the diameter of the axis.

PERIODICITY OF CAMBIUM

The vascular cambium in guava underwent definite periods of rest and activity during a calendar year. During the dormant stage the cambial zone was represented by a narrow zone of tangentially flattened cells consisting of 2-5 layers (Plates XXIV - XXVI). The radial walls of cambial cells during dormant stage were found to be comparatively thicker than what they were during the active phase. In tangential view, the radial walls exhibited prominently beaded appearance, during the resting period, due to alternately thickened areas and deeply depressed primary pit-fields, through which they communicated by plasmodesmata connections with the contiguous elements. Protoplasmic contents, including the nucleus, were relatively dense and stained dark during dormancy. The ray initials also accumulated more tannins during the dormant period and stained dark (Plate XXIII). The fusiform cambial cells, during their active phase, possessed relatively thin and almost smooth radial walls, due to the absence of thickened areas, alternating with the primary pit-fields (Plate XXIII). The beaded nature of radial walls, if at all present during the active period, was very light and not so prominent as in the dormant period (Plate XXIII). The cambial zone during the active phase, as a whole, took light stain due to the

absence of any coloured contents in the cells including the ray initials. The cytoplasm and the nucleus also lost their chromaticity, and therefore did not get stain dark. The zone, as a whole, became very delicate and got detached together with the bark from the wood even on a slight external pressure.

The vascular cambium in this species appeared to undergo activation twice in a year, after undergoing definite periods of rest. The first sign of activity occurred during March. The cells in the cambial zone underwent radial expansion in the last week of March and as a result the cambial zone swelled up. The enlargement of cells added about 20/u to the depth of the cambial zone. In early April the cell divisions occurred in the cambial population to increase the layers of cells from 2-5 to 5-7, and, as a result, the depth of cambial zone became 71/u in April from 36/u found in March (Plates XXIV - XXVI). The derivatives partly transformed into tracheary elements and, as a result, 50-60/u of new xylem was added in this month to the wood of the trunk and about 80/u of the phloem to the bark by the end of April. In the month of May the activity came to an end and the cambium slowly changed to its dormant phase during late May. However, no typical dormant structure of the cambium developed, although the signs of dormancy became somewhat visible during this temporary phase of rest. The cambial zone became somewhat narrow and was represented by a fewer layer of cells (3-5)

again in June and July. No new elements of xylem or phloem appeared to have been produced during this period. For all purposes the cambium remained inactive from the second half of May to the first half of July.

In mid-July of all the three years, the cambial zone was noticed to undergo the swelling phenomenon as it happened during the late-March of all the three years. The cambial zone, as a result of swelling, increased in its dimensions to the same extent as it had happened earlier, that is about 20/u. The actual cell divisions occurred in late July - early August and the new cells continued to form upto October (Plates XXIV - XXVI). Thus, the second phase of cambial activity extended for about 3 months in all the three years (Figure 33).

During the second phase of activity, as in the first flush, both xylem and phloem were produced in the same sequence. To start with, xylem elements were added and late in the season phloem production started. However, in the year 1975 the production of xylem and phloem was initiated a bit early i.e., in late-July and mid-September respectively. But in the other two years, due to the absence of enough rainfall in September the phloem production started a bit late i.e., in late-September and continued upto October (Figures 34-36). The amount of phloem produced in a calendar year including both the flushes of radial growth came about 400/u while the total xylem produced during the same period amounted to only 150-200/u i.e., just half of the phloem produced.

LONGEVITY OF PHLOEM

As mentioned earlier, the phloem production occurred in this species twice in a year, the first addition being in late-April to early-May, while the second at the close of the growth season i.e., late-September to October. In the first flush about 80-100/u of new phloem was produced and in the second about 300/u.

The small amount of new phloem produced out of the first flush got eliminated in September just before the second instalment of new phloem was added up. Thus what was produced in the first flush functioned for about 5 months (Figure 37).

The major part of phloem was produced out of the second flush of the radial growth in this species (300/u). A major part, out of this, became inactive in the following months i.e., in November and December of the same year, excepting a narrow strip, amounting upto 30/u in depth. The inactivation of phloem was brought about by the heavy accumulation of callose depositions which blocked the sieve pores both at the sieve plates as well as on the lateral walls of the sieve tube elements (Plates XVI, XXV, XXVI). However, the narrow strip of phloem situated adjacent to the cambium (Plates XXV, XXVI) remained active till April next or till the new phloem of the first flush of radial growth was produced (late-April). Thus the longevity of phloem of the second flush extended for about 7 months (Figure 37).

RELATION BETWEEN EXTENSION AND RADIAL GROWTH

A comparison of results obtained out of studies on extension growth of the selected branches and the radial growth of the trunk of the trees during the year 1974, 1975 and 1976 revealed the following facts:

1. Both the types of growths occurred in two apparent instalments in a calendar year, one preceding the other;
2. The extension growth always preceded the radial growth by 3-4 weeks.

In the present study, all the three years of the extension growth following the bud bursting, preceded 3-4 weeks the radial growth in the trunk. For instance, in 1974 the bud bursting occurred in early-March and the extension growth occurred at a rapid rate in April. Following this, the radial growth also occurred a bit late in this year as compared to 1975 and 1976. In 1975 and 1976 the extension growth started a bit earlier i.e., in late-February while the radial growth started in April i.e., after 4-5 weeks of the extension growth.

In short, both the flushes of radial growth in all the three years showed a definite relationship with the

extension growth. In no instance the radial growth was noticed to precede the extension growth. However, the cessation of cambial activity coincided with the closing time of the extension growth (Figure 38).

DISCUSSION

EXTENSION GROWTH:

Several tropical trees have been noted to have extension growth in more than one flush during one growing season by a number of workers (Cossmann 1939, Randhawa & Dinsa 1947, Greenwood & Posnette 1960, Cooper 1957, Chowdhury 1958, Koriba 1958, Alvim 1964, Kozlowski 1964). In the present study too, guava was found to have two apparent flushes of growth, the first occurring in February and the second in July. However, the two flushes of growth in this species is not separated by any duration of resting period as the first flush merges with the second before it goes on complete cessation of activity. In other words, the plant grows at different rates between February to October in an intermittent manner, with growth waves occurring at different rates so as to give rise to two apparent flushes of growth. A similar trend of growth occurring in a series of intermittent waves was reported by Cooper (1957) in the case of another tropical fruit tree viz., Citrus. Thus in guava the extension growth takes place for about 210-240 days, a duration which is much longer than what was reported for temperate angiosperms (Kramer 1943, Reimer 1949).

Under the classification of Koriba (1958), guava falls under the category of 'b' type in which the growth occurs intermittently with non-seasonal leafing.

Yanagisawa (1954) found clear correlation of the bud bursting with temperature and categorized the Japanese trees as early, medium and late flushing forms. The present study on guava also supports the view of Yanagisawa (1954), as this plant appears to be very sensitive to the prevailing temperature. In 1974, the bud bursting in guava was delayed by a fortnight to a month's period, as compared to the other two years of study. The delay in 1974 appears in all probability, due to the temperature effect coupled with low humidity. The materiological data collected during these years show that the mean temperature and relative humidity in February of 1974 is lower than what prevailed in the other two years. The mean temperature of February 1974 falls short by 0.9°C and 2.2°C as compared to February 1975 and 1976 respectively. This had caused the failure of bud bursting in 1974 and thus supports the view of the above Japanese worker that some species are temperature sensitive. In spite of the late initiation of extension growth in 1974, the height growth curve followed the same pattern as in 1975 and 1976. This confirms the findings of Tryon & Finn (1937), Friesner (1943) and Kramer (1943) who found similar height growth curves in successive years in the case of some Pinus and Picea spp.

Lammas and Proleptic shoots i.e., those resulting from bursting and elongation of current year terminal buds and those developing out of lateral buds arising at the base of terminal buds in the late season respectively (Kozlowski 1964), occur in guava as noted by a number of workers (Wight 1930, Anic 1956, Fraser 1958, Kramer & Kozlowski 1960).

In addition to the above, sylleptic shoots (branches forming out of axillary buds)of elongating shoots before they are fully formed) also occur in this species in large number particularly during the flowering season (Kozlowski 1964).

Majority of the terminal buds of both the leader shoots and the lateral ones, abort in guava and new buds appear in the next growth season. The loss of shoot tips occurs in a rather well defined pattern in this species. First the young leaves stop growing and new primordia failed to form. The shoot tips then yellows and abscises from the base of the internode. After the bud drops off, a protective layer forms over the area of severence. Similar observations were made in several other tropical woody species of Kozlowski (1971) and in a numberof temperate plants by Romberger (1963) and Millington (1963).

SEEDLING GROWTH:

It was noted by Wareing (1956) that in many woody plants the seasonal period of height growth is much shorter in mature trees than in seedlings. According to him the

seedlings of Robinia pseudo-acacia have a long growing season extending into autumn while in the mature trees the tip growth of many shoots stops by the end of July. Similar differences in growth activity among the young and old trees were noted by Kramer (1943), Young & Kramer (1952) and Sato et al. (1958). In the present study too, the extension growth of seedlings extended for a longer period than in the matured trees as in Robinia pseud-acacia (Wareing 1956) and Citrus (Sato et al. 1958). Further, the tip growth in seedlings occurs as a continuous process while the same in two apparent flushes in the matured trees.

SHOOT APEX:

The apical structure of shoots and roots of various plant groups was studied by a large number of workers and a number of reviews have appeared from time to time (Schmidt 1924, Foster 1939, Esau 1943a, Wardlaw 1945, Philipson 1949, Johnson 1951, Gifford 1954, Cutter 1959, 1965, Clowes 1961, Newman 1961, Romberger 1963, Gifford Jr. & Corson Jr. 1971). One to five layers of tunica have been reported for dicotyledons with two in the largest number of species; one to four for monocotyledons with one and two dominating (Gifford 1954, Thielke 1954, Hara 1958, Jentsch 1960). Guttenberg (1960), however, considered the tunica to be consisted of no more than

two layers which he termed as dermatogen and subdermatogen. Unlike in the majority of dicotyledons, in guava the tunica is made up of only one layer of cells as in some species of Bombax (Johnson & Tolbert 1960), in Clematis (Tepfer 1960), Euphorbia neriifolia (Shah & Jani 1964) and some Malvaceae (Tolbert & Johnson 1966).

Distinct cytohistological zones were recognized in the apical structure of some dicotyledons as in gymnosperms (Millington & Fisk 1956, Kundu & Rao 1957, Johnson & Tolbert 1960, Ramji 1960, Tepfer 1960, Codaccioni 1962, Gifford & Tepfer 1962, Kalbe 1962, Smith 1963, Shah & Jani 1964, Tolbert & Johnson 1966, West & Gunckel 1968a, b). In the present study three distinct histological zones were recognized viz., distal, proximal and peripheral, on the basis of the histochemical characteristics of the protoplasmic inclusions, cell shape and size.

The peripheral zone gives rise to the leaf primordia in this species as in the other dicotyledons. The development of leaf can be divided, for convenience, into three stages viz., formation of the foliar buttress, formation of the leaf axis and the formation of lamina. The leaf buttresses in guava develop by periclinal divisions in the corpus cells of the peripheral zone. An erect peg like protuberance, somewhat flattened on the adaxial side arises which forms the axis of the young leaf. As the leaf axis grows to the size of 50-80 μ the procambium differentiates in the median part in

continuity with the procambium of the internode below (Pray 1955a,b, Buvat 1955, Bailey 1956 and Esau 1965b). The lamina is initiated in early stages of elongation of the leaf axis i.e., before it reaches the size of about 100 µ while the leaf axis is still continuing its apical growth (Avery 1933, Foster 1936 and Mac Daniels & Cowart 1944).

The vascular element differentiates while the young leaf is about 230-250 µ in length. The first element to appear is the protophloem. The first protoxylem element appears after the formation of 3-5 sieve elements as noted by others in different species (Esau 1938, 1939, 1943a, 1945, 1950, 1954, 1965a, b, Sterling 1945, Gunckel & Wetmore 1946b, Sacher 1955a, b, Griffith 1957, De Sloover 1958, Parke 1963 and Ghouse et al. 1972). In the shoots of guava the differentiation of primary vascular elements follow the same trend as in the leaf axis i.e., the differentiation of phloem precede that of xylem as is the case in the majority of dicotyledons (Esau 1965a).

FORMATION OF VASCULAR CAMBIUM:

The vascular cambium in Psidium develops first between the primary xylem and phloem and then extends to the inter-fascicular regions to form a ring as in the majority of dicotyledons and gymnosperms (Esau 1965a). Cross section of young stems shows that there is a radial row of cells from which the primary vascular elements differentiate, as noted

by Esau (1936, 1938, 1942, 1943b, 1965b), Gunckel & Wetmore (1946a), Sterling (1946, 1947), Parke (1963), Thompson & Heimsch (1964), Cumbie (1967), Fahn *et al.* (1972), Ghouse *et al.* (1972), Soh (1972, 1974) and Butterfield (1976). The radial series of primary elements brought difficulty in recognising the formation of the true cambium out of the procambial initials. However, the differentiation of ray initials has been taken as the principal criterion to distinguish the true cambium from procambium (Catesson 1964).

STRUCTURE OF CAMBIUM:

The cambium in guava is made up of two types of initials, the fusiform and ray initials. The former is a long fusiform cell with parallel lateral walls and pointed ends, while the latter is almost isodiametric. The arrangement of the different initials in the cambial zone depicts a typical non-stratified structure. This type of cambium has been held as phylogenetically primitive by a number of workers (Bailey 1923, Eames & Mac Daniels 1947, Esau 1960, 1965a, Fahn 1967), as it is found in the structurally primitive dicotyledons, gymnosperms and in certain pteridophytes.

Although the ray initials are almost isodiametric, they are of heterogenous type in this species. Some of them are longer than others while still others, particularly those situated at the ends, are pointed at one end. In addition to this difference in shape and size, the ray initials form

two distinct systems, the procumbent and upright. Thus the size and shape, as well as the arrangement of the different initials, indicate further the primitive nature of vascular cambium in this species (Barghoorn 1940a, b, Esau 1960).

The ray initials aggregate to form long fusiform ray initial units, which, at times, are interrupted by the intrusion of adjacent fusiform initials, resulting in the splitting of the units into a number of small entities, as was noted by earlier workers in some tropical, as well as temperate plants (Barghoorn 1940a, b, Evert 1961, Cheadle & Esau 1964, Ghouse & Yunus 1974b, Ghouse et al. 1975a, b, 1976b). Contrary to the above, formation of long ray initial units, by the fusion of two or more such units, also occur in this species as noted in Dalbergia by Ghouse & Yunus (1973, 1974b) and in some arid zone species of Acacia and Prosopis by Ghouse & Iqbal (1975). This is also in confirmation with the findings of Barghoorn (1941), Braun (1955) and Evert (1961, 1963).

The fusiform initials form about 63-70% of the cambial zone depending on the seasonal effects on cell division and cell proliferation. This is in accordance with the proportion of fusiform initials noted by Ghouse & Yunus (1974a, b, 1976), Ghouse & Iqbal (1975) and Ghouse et al. (1975a, b, 1976b) in certain tropical trees, although it goes against the common concept that the fusiform initials form more than ninety percent of the cambial zone (Wilson 1963, 1964; Kozlowski 1971).

SEASONAL EFFECT ON THE STRUCTURE OF CAMBIUM:

The size as well as the proportion of fusiform initials is found to vary in relation to different seasons. The maximal and minimal size of fusiform initials has been noted in different months of a year. The size of oblique end walls also varies in different months as the total length of the initials.

Frequency of different ray initial units varies markedly during a year. Uniseriate rays are found to be more frequent in August and less so in October, whereas the broad rays are more during the winter season than in the active period. A similar trend has also been noticed in relation to the height of ray initial units.

During all the three years, the extent of area occupied by ray initials in the cambial zone happens to be the maximum (37%) in May and October, and the minimum in April. As a consequence of the above, the proportion of ray initials varies from 30-37% during a year. The amount of ray initials in the cambial zone, therefore, is much more than what was proposed by Wilson (1963, 1964) and found by Bailey (1923) and Butterfield (1972) in some dicotyledons. However, this is in agreement with the earlier findings on some tropical trees by Ghouse & Yunus (1973, 1974a, b and 1976), Ghouse & Iqbal (1975), Ghouse et al. (1975a, b) and Yunus (1976).

AGEING EFFECT ON THE STRUCTURE OF CAMBIUM:

The cambial make up undergoes considerable variation as the cambium ages. The fusiform initials are found to increase in length and width with the age of the cambium in addition to their number. The increase in cell size occurs in a gradual manner till they attain the maximal size and later a constancy follows. This variation trend is in confirmity with some earlier findings on some conifers and woody dicotyledons (Bailey 1923, Hejnowicz & Hejnowicz 1958, Evert 1961, Bannan 1962, Carlquist 1962, Ghouse & Yunus 1973). A similar change in the dimension of ray initials could not be noticed in the present study, although they are found to multiply to a greater extent and their relative proportion going high as the cambium ages. The magnitude of ray initials has been found to raise from 20 to 37% when their proportion was estimated in the current year shoot and in the trunk of an old tree (about 30 years old). A similar raise in the proportion of ray initials was reported by Ghouse & Yunus (1973) in the case of Dalbergia sissoo.

SEASONAL EFFECT ON THE STRUCTURE OF WOOD:

Although the vessels of three different types are produced in Psidium guajava viz., narrow, medium and large lumen types, they are not produced in any particular sequence

as this species is characterised with diffuse porous wood. It is, therefore, found difficult to ascertain the seasonal effect on the structure of wood which is largely determined by the pore size and arrangement of vessels.

AGEING EFFECT ON THE STRUCTURE OF WOOD:

The wood of current year shoot consisted of narrow lumen vessels in large number. As the axis grows older, the wood becomes poorer in the number of vessels, but at the same time, the lumen size of the vessels considerably increases. As a result the reduction in the number of vessels per unit area is compensated by the increment in the lumen size of the vessels. In spite of the decrease in the number of vessels per unit area of wood, the area occupied by these elements steadily increases with the increasing girth of the axis, as it happened in the case of sieve-tube cells in bark.

The vessel length as well as the fibre length undergoes a gradual increase with the increase in the girth of the stem axis till they attain their maximal size and then a constancy follows. Similar trend of variation of xylem tracheids and fibres has been enunciated by some workers who found that the mean length of these elements increases from the top down to the bottom initially and later, follows a constancy (Bailey 1923, 1944, Carlquist 1962, Cumbie 1963, 1967, 1969, Butterfield 1972,

1973, Pattanath 1972, Rao et al. 1973, Purukayastha et al. 1974). In general the trend of variation follows the same which was noted for the fusiform initials of the cambial zone described earlier.

SEASONAL EFFECT ON THE STRUCTURE OF BARK:

The depth of conducting phloem has been noted in the present study to vary from 30-400 μ in a calendar year. The maximum depth has been recorded in October. These findings are in confirmity with the general concept that the conducting phloem forms only a fraction of the total secondary phloem or of the functional bark (Esau 1965a), Lawton & Lawton (1971), Lawton (1972), Ghouse & Hashmi (1976) and Yunus (1976) have also observed varying amounts of conducting phloem in various months of a year in certain tropical species investigated by them. However, no significant difference in the lumen size of the sieve tube element has been noticed in the early and late formed members, as it was observed in the past (Münch 1943, Esau & Cheadle 1959, Evert et al. 1969, Tucker & Evert 1969, Lawton 1972).

The observations recorded in the present study on the extent of sieve-tube members in the conducting phloem do not agree with those found by the earlier workers (Münch 1930, Crafts 1931, 1933, Geiger et al. 1969, Evans et al. 1970,

Lawton & Canny 1970, Lawton 1972, Ghouse & Hashmi 1976, Ghouse et al. 1976a). However, the author agrees with the suggestion of Lawton (1972), Ghouse & Hashmi (1976) and Ghouse et al. (1976a) to investigate the structural details of phloem prior to physiological studies pertaining to translocation, instead of accepting an arbitrary value to calculate the specific mass transfer through phloem as advocated by Lawton & Canny (1970) and Canny (1973) recently.

AGEING EFFECT ON THE STRUCTURE OF BARK:

The amount of bark has been found to vary in the axis of varying age from 0.05 to 1.0 cm. Almost a gradual increase in the bark thickness has been noted in the present study from the youngest axis to the oldest trunk analysed. The amount of actual conducting area has also been found to undergo a gradual increase with the increasing size or age of the axis. A similar trend of variation both in the amount of bark as well as in the amount of actual conducting area in relation to the increasing girth of the axis has been reported by Yunus (1976) in the case of Dalbergia sissoo.

The size of sieve-tube members has been found to increase in a gradual manner from younger to older axis till they attain the maximal size and then they remain more or less constant

after experiencing a slight decline. However, both the anticlinal and periclinal diameters of sieve-tube cells have been found to undergo a gradual increase with the increasing girth of the axis or from the top to the bottom of the tree. A similar trend of size variation of sieve-tube members in relation to the age of the axis was reported by Yunus (1976) in the case of Dalbergia sissoo and by Iqbal & Ghouse (1977) in Prosopis spicigera.

PERIODICITY OF CAMBIUM:

In majority of the hard wood species the function of cambium is periodic rather than continuous except in a few cases (Acacia raddiana, A. tortilis, Tamarix articulata) which grow in tropics where the growth factors are favourable throughout the year (Alvim 1964, Fahn 1967, Philipson et al. 1971). Although a considerable amount of work has appeared on the cambial activity of temperate trees (Studhalter et al. 1963, Esau 1965a, Koslowski 1971 and Philipson et al. 1971) for review. The information on the periodicity of cambial activity in tropical plants still remains to be far from complete (Chowdhury 1940, 1968, 1969, Fahn & Sarnet 1963, Fahn 1967, Paliwal & Prasad 1970, Lawton 1972, Rao 1972, Paliwal et al. 1975, Yunus 1976).

It was Priestley et al. (1933) who indicated for the first time the ease with which the bark is peeled off from

the plant body while the cambial activity is on. Several criteria have been introduced by subsequent workers to recognise the active cambium from its dormant phase (Knudson 1913, Lodewick 1928, Priestley *et al.* 1933, Wight 1933, Chowdhury 1939, Preston & Wardrop 1949, Hodge & Wardrop 1950, Wareing 1951, Ladefoged 1952, Preston & Ripley 1954, Samish 1954, Wardrop 1954, Wareing & Roberts 1956, Wilcox 1962, Esau 1965a, Waisel & Fahn 1965a, b, Srivastava & O'Brien 1966, Fahn 1967, Waisel *et al.* 1970). The number of layers of undifferentiated cells present in the cambial zone has been emphasised to indicate the cambial condition by Paliwal & Prasad (1970) and Paliwal *et al.* (1975) in the case of *Dalbergia sissoo* and *Polyalthia longifolia* respectively. However, Waisel & Fahn (1965a) introduced a more accurate criterion based on radiological method to study the cambial activity.

At the advent of the favourable season, the reactivation of cambium takes place and it is generally indicated by the slight increase in the size of the initials, especially in radial direction - a phenomenon what was described as swelling of the cambial zone (Chowdhury 1969, Paliwal & Prasad 1970, Paliwal *et al.* 1975, Yunus 1976). A similar increase in the size of the cambial initials has been noticed in the present study, prior to cell division in the cambial zone of guava (Plate XXV). A decrease in the density of the cambial cell

protoplast and cell wall thickening, particularly the radial walls of the fusiform initials have occurred following the repeated cell division in the cambial cells as was noted in the case of Dalbergia sissoo (Paliwal & Prasad 1970, Polyalthia longifolia (Paliwal et al. 1975) and Robinia pseud-acacia (Derr & Evert 1967).

Various environmental factors, as well as several internal conditions, are known to have significant influence on the cambial activity. Among such factors are temperature, relative humidity, rainfall, light, geographic location, photosynthesis, water deficiency, endogenous hormones, leaf fall, fruit bearing pattern and the age of the plant (see Kozlowski 1962, 1971). Considerable efforts have been made to relate the effect of temperature (Bannan 1955, Eggler 1955, Fraser 1956, Wareing 1958, Kozlowski et al. 1962, Wort 1962, Alvim 1964, Waisel & Fahn 1965b, Paliwal & Prasad 1970, Paliwal et al. 1975, Yunus 1976), duration and intensity of light (Wareing & Roberts 1956, Fritts 1958, Fahn 1959, Fraser 1962, Philipson et al. 1971), water supply and age of the plant (Waisel et al. 1970), rainfall (Aljaro et al. 1972, Lawton & Lawton 1971, Lawton 1972), fruit bearing habit (Evert 1961) and the age of the tree (Bannan 1967).

The present study indicates that the cambial activity in Psidium guajava is not only influenced by the physical factors like temperature, rainfall and relative humidity (Figs. 34-36) but also by such physiological factors, as bud

bursting, leaf initiation, flowering and fruiting. In all the three years of the present study, the swelling phenomenon of the cambial zone has been recorded in late March and the actual cell division in early April. The monthly average of temperature in March happened to be 23.1, 21.1 and 21.2°C in the years 1974, 1975 and 1976 respectively, while the relative humidity during this period in the above years was 43.3, 58.5 and 46.4% respectively. This indicates that for the first phase of reactivation of cambium in Psidium i.e., to initiate the swelling phenomenon, a minimum of 21°C and 43.3% relative humidity appear to be essential, although a higher temperature (a minimum of 27.4°C) is needed to initiate the actual cell division in the swollen cells of the cambium.

The cambial activity, initiated in April, does not lost long and the cambium appears to undergo a period of rest for about 3 months. Again, in the last week of July under high humidity and temperature, the cambium comes into action and produce the major part of its products in the following months, after undergoing a swollen phenomenon in late July. The two flushes of cambial activity, noted in this species, is the first of its kind and this may be related to the peculiar habit of this plant in having two distinct periods of extension growth followed by new leaf production and fruting twice in a year. A similar, but not identical, relation of cambial

activity was noted in Pyrus communis by Evert (1961). The frequency of anticlinal divisions in the fusiform initials altered from year to year and the plants exhibited the same phenomenon in alternate fruiting years and thus a relationship between the alternate fruit-bearing habit of the plant and the cambial behaviour was established in Pyrus communis. Further studies on more species having such alternate bearing like Pyrus and those yielding more than one crop in one season like guava are needed before any general conclusion could be made on the seasonal behaviour of vascular cambium in such plants.

XYLEM AND PHLOEM PRODUCTION:

In guava xylem and phloem production occurs in different periods, the former preceding the latter, unlike in the other diffuse porous woody dicotyledons (Acer negundo, Tucker & Evert 1969; Pyrus communis, Evert 1960; Pyrus malus, Evert 1963; Populus tremuloides, Davis & Evert 1968), excepting Tilia americana (Evert 1962, Deshpande 1967 and Vitis riparia (Davis & Evert 1970), diffuse porous forms in which the xylem and phloem differentiate simultaneously. The present findings that xylem differentiation precedes that of phloem has also been reported by some earlier workers (Elliott 1935, Artschwager

1945, Fraser 1952, Bannan 1955). However, the reports on phloem formation preceding xylem production are not uncommon in literature (Knudson 1916, Cockerham 1930, Huber 1939, Esau 1948, Derr & Evert 1967, Alfieri & Evert 1968, Tucker & Evert 1969, Davis & Evert 1970, Lawton 1972).

LONGEVITY OF PHLOEM:

The presence of functional sieve elements year round in woody dicotyledons has been reported for but a few species (Esau 1948, Holdheide 1951, Evert 1962, Fahn 1967). The phloem, in the majority of the plants becomes nonfunctional in the same season in which they are derived from the cambium (Elliott 1935, Esau 1939, 1945, 1950, Huber 1939, Artschwager 1950, Holdheide 1951, Evert 1960, 1963, Davis & Evert 1968, 1970, Tucker 1968, Tucker & Evert 1969). In guava the phloem functions only for the season in which it is produced as in the majority of woody dicotyledons. However, in this species, the phloem is produced in two distinct flushes, the first being in late April to mid-May and the second in late September to October. What is produced in the first flush, becomes non-functional soon after the second instalment is produced at the close of the growth season i.e., the first flush of phloem added functions for a period of about 5 months. Out of the second flush of phloem, added in September and October, a major

part gets blocked up with callose depositions during the winter (definitive callose), while a narrow strip, amounting upto 30/u in depth, remains functional. This too gets eliminated in April when the new phloem is produced after the cambium is reactivated and thus the phloem of second flush functions for a period of about 7 months.

In guava no sieve-tube element appears to revive back to action in spring after winter, as it happens in Pinus strobus (Alfieri & Evert 1968), Pseudotsuga taxifolia (Grillos & Smith 1959), Quercus alba (Anderson & Evert 1965), Tilia americana (Evert 1962), Ulmus americana (Tucker 1963), Vitis rinaria (Davis & Evert 1970) and V. vinifera (Esau 1948). No undifferentiated precursor phloem has been noted in this species as was reported by Strasberger (1891), Brown (1915), Abbe & Crafts (1939), Artschwager (1950), Wilcox et al. (1956), Grillos & Smith (1959), Evert (1960, 1963), Srivastava & O'Brien (1966), Derr & Evert (1967) and Davis & Evert (1968, 1970).

RELATION BETWEEN RADIAL AND EXTENSION GROWTH:

A direct relationship between the bud bursting and the initiation of radial growth has been noticed in the present study as it was observed by Palival & Prasad (1970), Rao (1972) and Yunus (1976). The radial growth occurs after a month of

initiation of extension growth in guava and this has been recorded in all the three years of study. Chowdhury (1939, 1940, 1958, 1969), Chowdhury and Tandon (1950) also reported that, as a rule the extension growth precedes the radial by 2-12 weeks in broad leaved trees of India.

Cessation of radial growth also showed a direct relationship with the extension growth in all the three years of the present study. However, the cambial activity comes to an end along with the extension growth unlike in Dalbergia sissoo in which the cambial activity proceeds for a month or a little more, even after the cessation of extension growth (Yunus 1976).

PERIDERM DEVELOPMENT:

Studies performed in the past (Sanio 1860, Moller 1882, De Bary 1884, Douliot 1889, Muhldorf 1925, Pfeiffer 1928, Metcalf & Chalk 1950, Chattaway 1953, 1955, Lier 1955, Schneider 1955, Bowen 1963, Esau 1964, Fahn 1967, Waisel et al. 1967, Arzee et al. 1968, 1970, Ahmad et al. 1969, Ghouse & Yunus 1975), clearly indicate that the site and time of origin, duration and mode of activity of phellogen shows quite a wide range of diversity among the different plants.

The developmental details of periderm in guava reveal that the initiation of first phellogen takes place in dispersed loci to begin with and later forms a ring by lateral extensions. The initiation of periderm formation takes place in the pericyclic cells just below the fibre ring against the ridges. Subsequently meristematic activity slowly spreads in tangential directions and finally forms a continuous ring at the periphery of the stele (Lier 1955, Schneider 1965, Arzee et al. 1968, 1970, Ahmad et al. 1969, Ghouse & Yunus 1975).

The first phellogen in guava functions for a short period as in the majority of the woody plants (Eames & Mac Daniels 1947). The subsequent periderms develop at successively deeper layers in the secondary phloem and do not form a complete ring as the first phellogen as in Dalbergia (Ghouse & Yunus, 1975).

New phellogen formation occurs every year as the previous phellogen becomes inactive and gets peeled off in flakes as a result of the strain created by the increase in the stem circumference by the addition of cambial derivatives (Whitmore 1962, Evert 1963, Ghouse & Yunus 1975).

The formation of periderm in roots of guava follow the same pattern as in the shoot, however, the phellogen once formed continues to function as long as the root exists.

SUMMARY

The anatomical study on the growth activities of guava (Psidium guajava) has been carried out for three consecutive years starting from 1974. The results are summarised below:

The extension growth normally starts from late February or early March and continues upto the end of October. Its rate slows down considerably during May and June giving rise to an apparent break in growth.

The new leaves appear throughout the period of extension growth. With the production of new leaves, new axillary buds arise. These buds develop into short branches and produce floral buds and dry up with the ripening of the fruits.

The flowering occurs in two flushes, the first from the middle of March to May and the second from July to September.

The extension growth in seedlings starts from February and continues upto October without any apparent break.

The shoot apex possesses a distinct tunica layer and a mass of corpus cells constituting the distal, the proximal and the peripheral zones. During the differentiation of primary vascular elements, phloem formation precedes xylem in

the shoot axis as well as in the leaf axis.

Transections of young shoots are quadrangular in outline. The cortex bears a number of secretory ducts of various dimensions. Next to cortex, a continuous cylinder of thick walled parenchyma represents the pericycle which encloses a vascular cylinder, with a centrally placed parenchymatous pith. On the periphery of the pericycle, develops a discontinuous fibre ring. In nodal regions brachysclereids develop in the cortex and pith.

Roots are tetrarch.

The first phellogen initiates in the pericycle both in root and shoot. Subsequent periderms replace the older ones in older shoot axes.

The petiole and midrib have a crescent shaped vascular strand with incurved ends. The secretory ducts develop below the epidermis. The mesophyll of blade differentiates into palisade and spongy parenchyma. A distinct multilayered hypodermis develops below the adaxial surface.

A foliar cambium, with distinct ray and fusiform initials, develops in the main vascular strands of leaves and petiole, and produce some secondary elements.

The vascular cambium is non-stratified and is made up of fusiform and ray initials. The fusiform initials vary in

length from 308-423/u. The nuclear number in fusiform cells varies from 1-5 per initial. The number, size, shape and the chromaticity of the nucleus as well as the thickness of radial walls of fusiform initials appear to undergo considerable seasonal variations.

The number of cambial layers goes high in the month of April and August. The fusiform initials attain maximal size (397/u) in July. The frequency of the uni-seriate ray initial units appear more in August and September.

Changes in the cambial make up also occur with the growing age of the axis. The fusiform initials undergo gradual elongation with the growing age of the axis. The ray initials mainly multiply to become more in number. The ray initial units become broad and occupy greater area in the older axes than the younger ones.

The wood of guava is diffuse porous. The axial parenchyma is apotracheal and diffuse. The wood rays are heterogenous and vary in height from 1-40 cells and in width from 1-5 cells.

The vessel size varies with the season and age of the plant. The short vessels are more frequent in the younger ones than in the older trunks.

The bark of adult trees is non-fibrous and is made up of conducting and non-conducting zone. The extent of cross-sectional area of sieve-tube elements varies from 33-43% in a calendar year.

The vascular cambium undergoes activation twice in a year, after undergoing definite periods of rest. The first sign of activity occurs in March, with the swelling phenomenon taking place in the last week of March. The actual cell division occurs in early April. In May the activity stops and the cambium becomes dormant again. In mid-July the cambial zone again undergoes swelling phenomenon. The actual cell divisions start in late-July or in early-August, and the new cells continue to form upto October. Thus, the second phase of cambial activity extends for about 3 months. The total period of cambial activity, including the temporary phase of dormancy is about 8 months in this plant.

During both the phases of activity the xylem formation precedes phloem. The amount of phloem produced in a calendar year measures about 400/u in depth. The annual increment of xylem, on the other hand, amounts only to 150-200/u.

The phloem produced out of the first flush of cambial activity functions for about 5 months. The major part of the phloem of second flush (in September-October) becomes inactive in November and December of the same year. A narrow strip, amounting upto 30/u in depth, of the second flush, remains active till April next. Thus the longevity of phloem of second flush extends for about 7 months.

Extension and radial growth in Psidium occur in two apparent flushes. The extension growth always precedes the radial growth by 3-4 weeks. The cessation of cambial activity in trunks and the end of extension growth in twigs occur more or less at the same time.

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* Original not seen.

PLATE I. A 30 year old tree of *Psidium guajava*.

PLATE II. Bark morphology and branching in *Psidium guajava*

A - A young, tender shoot showing abundant epidermal hairy outgrowths and a floral bud (B) with axillary secretory appendages (BA), at 9x.

B - A branch showing pseudo-dichotomous branching, at -13x.

C - The main trunk of a twenty year old tree showing peeling of the dead outer bark, at -12x.

D - A main trunk after peeling of the dead outer bark at -12x.

PLATE III. Photomicrographs showing the structure of shoot apex, procambium and the transformation of procambium into vascular cambium in *Psidium guajava*.

A - A median longitudinal section of the shoot apex showing a single layered tunica and a mass of corpus cells grouped in different histological zones (distal, proximal and peripheral), at 530x.

B - A median longitudinal section of shoot apex showing procambial strand (arrow), at 530x.

C - A median longitudinal section of shoot apex showing the leaf trace (procambial strand) joining the axial procambial strand, at 33x.

D - Tangential longitudinal section of young developing twig showing the procambial strand (arrows) with cells arranged in storied order, at 133x.

E - A tangential longitudinal section passing through transforming procambial strand into vascular cambium. Note the non-stratified arrangement of the elements and the appearance of ray initials (RI), at 530x.
(All are Haematoxylin-Bismark brown preparations).

PLATE IV. Microphotographs showing the procambial strand and the formation of primary vascular elements in a developing shoot axis of Psidium guajava.

A - A transection of an internode showing a ring of procambium (arrow), at 36x.

B - Procambium (arrow) in tangential view, at 133x.

C - F. Transections showing the differentiation of primary vascular elements and the proportion of phloem and xylem (arrows), all at 350x.

(All are Haematoxylin-Bismark brown preparations).

PLATE V. Photomicrographs of transections showing the structure of primary and secondary phloem in a developing shoot of *Psidium guajava*.

A - Shows the peripheral protophloem (arrow) and the inner protoxylem (arrow), at 530x.

B - Shows the crushing of protophloem and the differentiation of metaphloem with sieve-tubes having companion cells (arrow), at 530x.

C - Shows the newly formed secondary phloem (arrow) with big parenchyma cells and ray cells fully loaded with tanniferous substances, at 600x.

D - An inner phloem strand with radially seriated primary elements (arrow), at 530x.

(All are Haematoxylin-Bismark brown preparations).

PLATE VI. Transections of a developing shoot of Psidium guajava indicating the development of pericyclic parenchyma below the fibre ring.

(A Haematoxylin-Safranin preparation).

A - An early stage showing the just obliterating groups of protophloem (arrow), a ring of procambium with radially seriated components, at 133x.

B - A narrow zone of pericyclic parenchyma, situated below the fibre ring and above the protophloem (arrow), at 133x.

C - Shows the cell divisions in different planes (arrows) in pericyclic parenchyma cells, at 566x.

D - Shows a broad zone of pericycle placed between the fibre (arrow) strand and the obliterated protophloem (arrow), at 530x.

PLATE VII. Photomicrographs of transections passing through nodal regions of *Psidium guajava* showing groups of stone cells.

A - Stone cells (arrows) of pith region with lamellated thickenings on wall and a broad lumen, at 600x.

B & D - Stone cells (arrows) at leaf gaps B at 150x, and D at 53x.

C - Shows the stone cells (arrow) at pith and at the inner cortex, at 75x.

(All are Haematoxylin-Bismark brown preparations).

PLATE VIII. Photomicrographs showing the median longitudinal sections of axillary buds at different stages of their development. Arrows in A indicate the axillary meristem and in D the procambial strands. A and C at 33x. B at 160x, D at 170x.

(All are Haematoxylin-Safranin preparations).

PLATE IX. Photomicrographs showing the various stages of periderm development in Psidium guajava stem.

A-D. Haematoxylin -Bismark brown preparations.

E-F. Lacmoid preparations.

A - Initiation of phellogen (arrow) formation below fibre groups, at 133x.

B - Enlargement of 'A', at 530x.

C - Phellogen (arrow) ring, at 150x.

D - Enlargement of 'C', at 840x.

E - Transection of an old trunk showing two bands of periderm, outer and inner (arrows), at 28x.

F - Enlargement of 'E', at 600x.

PLATE X. Transectional view of young roots of *Psidium guajava* showing the structure before and after secondary growth.

A - A young root before the formation of cambium, at 100x.

B - A root after secondary growth (arrow), at 27x.

C - Site of initiation of vascular cambium (arrows), at 412x.

D - A just formed wavy cambial ring (arrow), at 450x.

(All are Haematoxylin-Bismark brown preparations).

PLATE XI. Photomicrographs showing the various stages of periderm development in the roots of *Psidium guajava*.

(A Haematoxylin-Bismark brown preparation).

A & B - The initiation of phellogen at the periphery of stele in the outer layer of pericycle A, at 150x, B, at 530x.

C - A young periderm with differentiating phellem (arrow) and phelloderm cells, at 300x.

D - Well developed periderm showing outer phellem, a narrow layer of phellogen (arrow) and a single layer of phelloderm, at, 530x.

PLATE XII. Transections of roots showing lateral root formation in Psidium guajava.

(A Haematoxylin-Safranin preparation).

A - A root before lateral root formation, at 100x.

B & D - An emerging lateral root (LR) placed within the cortex. B, at 100x, and D, at 500x.

C - A newly emerged lateral root, at 33x.

PLATE XIII. Photomicrographs showing the vascular details of foliar organs of *Psidium guajava*.

(A Haematoxylin-Bismark brown preparation).

A - Transection of petiole showing crescent shaped vascular strand, at 33x.

B - Transection of midrib. Arrows indicate the fibre groups, at 110x.

C - Tangential longitudinal section passing through the foliar cambium. Arrows indicate ray initials with black contents, at 530x.

D - Enlargement of 'A'. Arrow indicates the foliar cambium in transectional view, at 700x.

PLATE XIV. Photomicrographs showing the wood structure of *Psidium guajava* and its components.

A - A Haematoxyline-Bismark brown preparation of wood showing ray and axial parenchyma with black contents in transectional view, at 100x.

B - A transection of wood (20/u) stained with Lacmoid showing crystalliferous axial parenchyma (CR), at 530x.

C - Tangential view showing fusiform rays with cells containing dark contents and giant parenchyma cells with a single large crystal (CR) in each, at 530x.

D - Radial longitudinal section showing the heterogenous rays with procumbent and upright cells (arrow), at 530x.

E - Macerated vessel elements and xylem fibres, at200x.

PLATE XV. Photomicrographs showing the structure of bark and lenticel of *Psidium guajava*.

A - A transection of Haematoxylin preparation showing a non sclerified bark, at 150x.

B & C Transections of Lacmoid preparation showing sclereid bands (arrows) in the bark B, at 150x, and C, at 33x.

D - A lenticel in vertical view, at 530x.

PLATE XVI. Tangential longitudinal sections passing through the region of conducting phloem of *Psidium guajava*.

A - Shows the arrangement of sieve-tube elements (arrows), forming vertically running long tubular channels, at 133x.

B - A lacmoid preparation of winter phloem showing sieve elements with oblique end walls having compound sieve plates (arrows) with full of callose depositions associated with companion cells, at 530x.

C - A lacmoid preparation of winter phloem showing sieve elements with lateral sieve areas (arrows) occluded with callose. depositions, at 530x.

D - A sieve element with its associated companion cell (arrow), a tannic acid-Ferric chloride preparation, at 530x.

PLATE XVII. Photomicrographs of non-conducting phloem of

Psidium guajava.

A - A transection of Lacmoid preparation showing the sieve elements some undergoing obliteration and others with occluded callose depositions (arrows), at 530x.

B - A tangential view of 'A' showing sieve elements with their associated companion cells before their obliteration. The right arrow indicates the degenerating compahion cell. The left arrow indicates the deformed sieve plate with callose depositions, (a Lacmoid preparation), at 530x.

C - A transection of Lacmoid preparation showing the complete obliteration (arrows) of sieve-tube elements. The cells with dark contents are axial parenchyma, at 530x.

D - A tangential section of 20/u thickness stained with Potassium iodide showing rows of crystalliferous axial parenchyma cells of non-conducting phloem.
(Note the absence of sieve elements).
At 530x.

PLATE XVIII. Potassium iodide preparations of secondary phloem and wood showing the intensity of starch accumulation in *Psidium guajava*.

A - Transection of conducting phloem of the November sample showing traces of starch (arrows) in ray parenchyma cells, at 133x.

B - Transection of non-conducting phloem of the February sample showing the abundance of starch (arrows) in ray as well as in the axial parenchyma cells, at 133x.

C - Tangential section of conducting phloem of the May sample showing traces of starch (arrows), at 100x.

D - Tangential section of non-conducting phloem of the Februnry sample showing abundance of starch (arrows) accumulation in ray and phloem parenchyma cells, at 100x.

E - Transection of a wood sample of August showing poor starch accumulation only in ray parenchyma (arrow) at 530x.

F - Transection of a wood sample of February showing rich accumulation of starch (arrows) both in ray and axial systems, at 530x.

PLATE XIX. Photomicrographs depicting the crystalliferous parenchyma (arrows) in the conducting (A, B) and non-conducting phloem (C,D) of *Psidium guajava*. All are Potassium iodide preparations.

A - Transection, at 530x.

B - Tangential longitudinal section, at 530x.

C - Transection, at 530x.

D - Tangential longitudinal section, at 530x.

PLATE XX. Photomicrographs of cambial strips in tangential view, showing the variation in the structure and composition of the components due to the difference in age (A-C) and season (D-F).

A, B and C are Haematoxylin preparations.

D, E and F are stained with Foster's Tannic acid-Ferric chloride.

A - Current year shoot showing mostly uni-seriate ray initials.

B - A four year shoot showing mostly bi-seriate ray initials and slightly longer fusiform initials than in 'A'.

C - A cambial strip of adult tree trunk showing comparatively broad ray initial units and longer fusiform initials than 'A' and 'B'.

- An active cambial strip (April sample) showing thin radial walls without beeds and light coloured ray initials.
Note the fusion of some ray initial units uniting together in vertical direction.

E - A cambial sample of September showing almost similar structure as that of April excepting radial walls which were slightly thick here.

F - A cambial strip of November collection showing the beginning of winter structure i.e., the appearance of beads on radial walls and dark contents in ray initials.

All are at 133x.

PLATE XXI Cambial preparations stained with Tannic acid - Ferric chloride, showing nuclear shape, structure and number in tangential view.

A, C and D, at 800x.

B, at 530x.

PLATE XXII. Photomicrographs of cambial preparations in tangential view, showing the developmental changes in ray initials.

A, B, C are Tannic acid - Ferric chloride preparations; D and E are Haematoxylin preparations.

A - Shows the splitting of ray units by the elongation of ray initials by apical intrusive growth to form fusiform-like elements (arrows), at 170x.

B - Shows the mode of formation of new ray initials. Right arrow indicates the newly formed terminal segment of a fusiform cell, the future ray initial. Left arrow indicates a row of four newly formed ray initial, formed out of a segment of fusiform initial cut off the side, shown in 'C'. Both at 600x.

D & E - Show the lateral fusion of two adjacent ray initial units (arrows). Both at 700x.

PLATE XXIII. Cambial preparations showing radial wall thickness and ray initial contents at different phases of activity under high magnification.

A and B at 550x. C, D and E at 530x.

A - A February collection showing stout beads on radial walls and dark contents in ray initials.

B - A March collection indicating thicker beads and beginning of disappearance of dark ray initial contents.

C - An August collection showing thin radial walls without beaded structures.

D - Late September collection showing the appearance of beads.

E - A December collection showing prominance of beads and accumulation of tanniferous substances in ray initials.

PLATE XXIV. Photomicrographs of Haematoxyline preparations of transections passing through cambial zone, showing structural changes of cambium and the production of its derivatives.

A - A dormant cambium of March collection, showing a narrow strip of cambial zone, at 600x.

B - A sample of April indicating the initiation of new phloem formation and the enlargement of cambial zone after periclinal divisions in the initials, at 530x.

C - An August sample showing active cambium with new xylem production, at 530x.

D - An early september collection showing broad zone of cambial population, a few initials (arrow) undergoing periclinal division, at 530x.

CZ - Cambial zone; NP - New phloem; NX - New xylem. Vertical lines indicate the depth of cambial zone.

PLATE XXV. Photomicrographs of cambial preparations with Lacmoid stain, showing the different phases of cambium. A and C, at 510x; B and D, at 530x.

A - Shows a dormant cambium coupled with previous year's xylem below and callose deposited phloem above - a February collection.

B - A sample of March showing the swelling of cambial initials (arrows) before cell division. OP - Old phloem; OX - Old xylem.

C - A sample of late September showing a broad cambial zone (CZ) flanked by newly formed phloem (NP) and xylem (NX).

D - A December collection showing a narrow zone of dormant cambium (CZ) flanked by lignified xylem and callose occluded sieve elements.

PLATE XXVI. Photomicrographs of samples showing cambial derivatives in different seasons. A, B and D at 530x; C at 480x.

A - A collection of May showing the first flush of cambial derivatives. CZ - Cambial zone; NP - New phloem; NX - New xylem.

B - An October collection showing a broad zone of new phloem (NP) and xylem (NX).

C - A November collection approaching dormancy. Arrow indicates accumulation of callose in sieve-tube cells. CZ - Cambial zone.

D - A February collection showing a fully dormant cambial zone (CZ) and phloem with full of callose depositions (arrows).